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Sources and Magnitudes
of Water Quality Constituents of Concern
in Drinking Water Supplies
Taken From the Sacramento-San Joaquin Delta

Prepared for the CALFED Bay-Delta Program
by
Richard Woodard

September 22, 2000

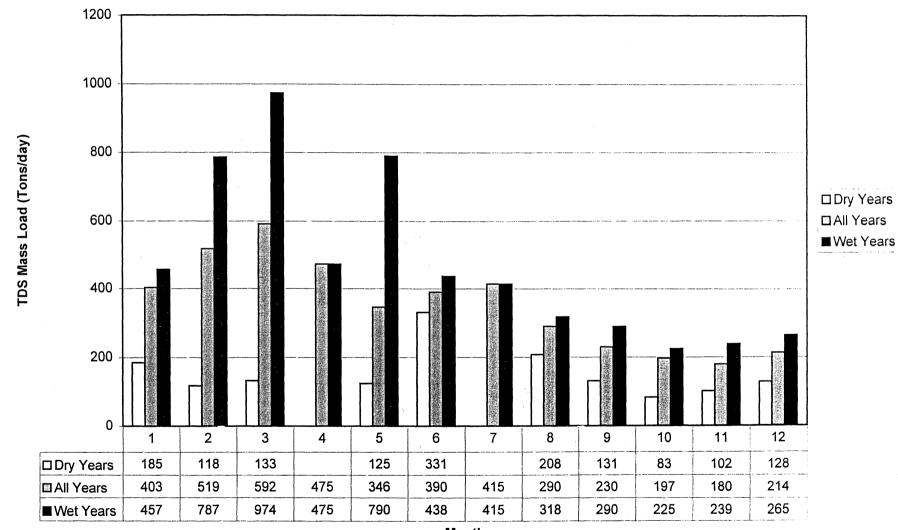
- Mass Load (Tons/Day) Concentration (mg/L) 66/12/1₁ 60/13/ 66/1_{5/6} 86/12/11 och sir 16/12/11 16/12/1 16/12/6 96/12/1₁ %/2/₁ %/_{2/5} Solvely 56/15/5 BO/12/1/ AGIVELY *6/12/6 66/12/11 66/476 6/12/11 CO/CI/ 26/12/5 16/12/11 16/12/ 16/12/5 06/12/1/ 06/_{12/} 06/12/5 9 10000 1000 100 Total Dissolved Solids

TDS in American R @ WTP

227

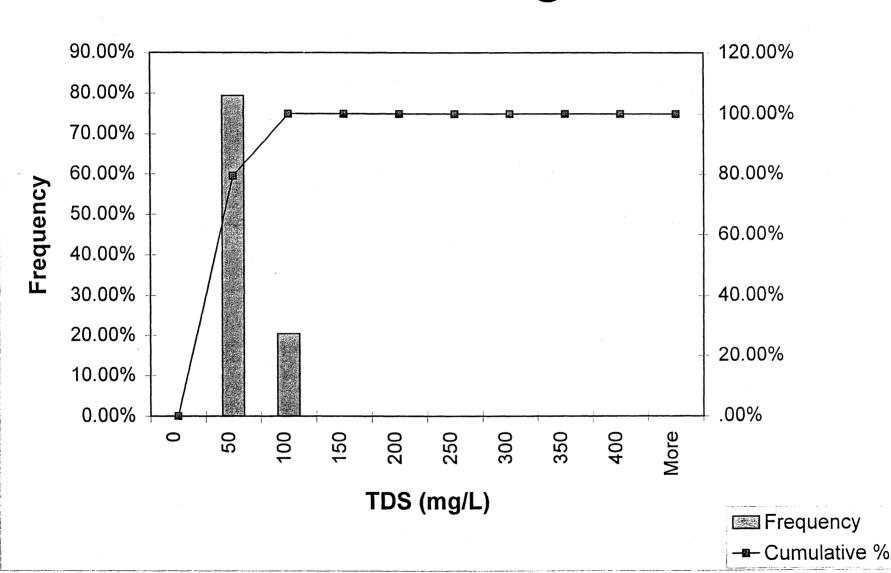
Month

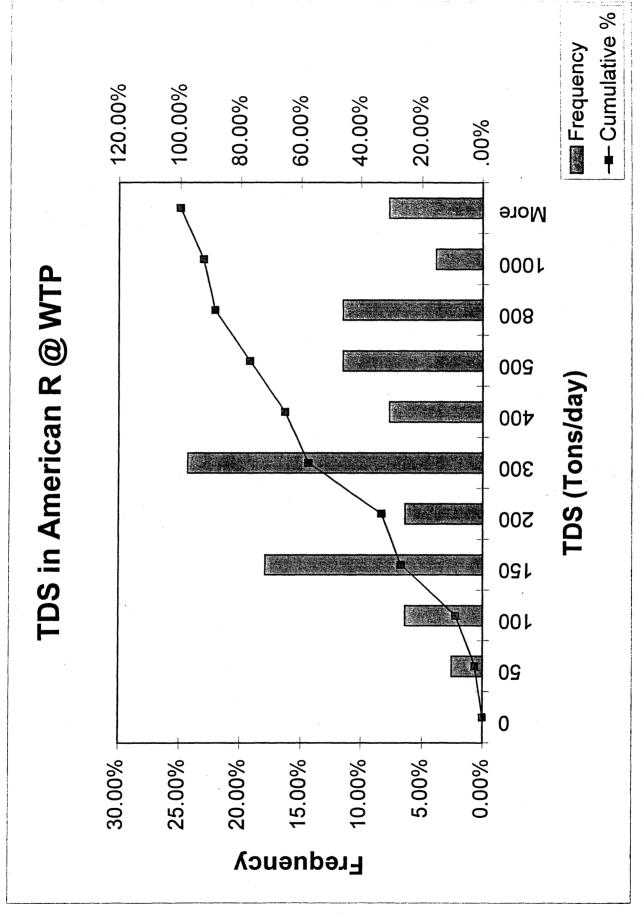
TDS in American R. @ WTP



Month

TDS in American R @ WTP





Delta Island Drainage

Characterization of Delta island drainage is based on over 1400 drainage samples collected from 25 Delta islands by the Department of Water Resources, and drainage volume estimates by the Department.

Figure 6-28 shows that TDS concentrations in island drainage tend to increase during the wet months, probably due in large part to planned salt leaching to maintain the productivity of the soils. Concentrations tend to be higher in dry years. Figure 6-29 depicts computed mass loads of TDS from island drainage. Wet months tend to be associated with greater loadings, particularly in wet years. The reader should keep in mind the fact that TDS in island drainage is largely a function of concentration of salts in water applied to the land by evaporation and plant transpiration. While island activities increase TDS concentration, the mass load in the applied water may be little affected by island operations.

Diversions

Total dissolved solids in the major drinking water diversions from the Delta are discussed below.

North Bay Aqueduct, State Water Project

Figure 6-30 shows historical TDS concentrations and mass loads in waters of the North Bay Aqueduct. Long-term trends of change are not apparent.

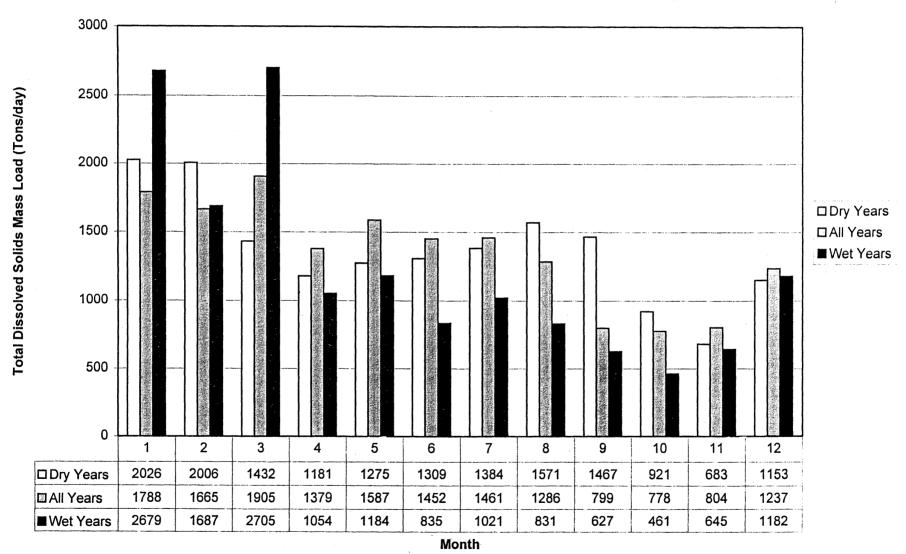
Monthly summaries, presented in Figure 6-31 indicate the months of March through May are characterized by elevated concentrations in dry years especially. As shown in Figure 6-32 much of the TDS loading occurs during the spring and summer months. The distribution of TDS concentrations (Figure 6-33) shows the most frequently observed concentrations are in the range of 200 to 250 mg/L; the most commonly observed range of loads is 30 to 40 Tons/day (Figure 6-34).

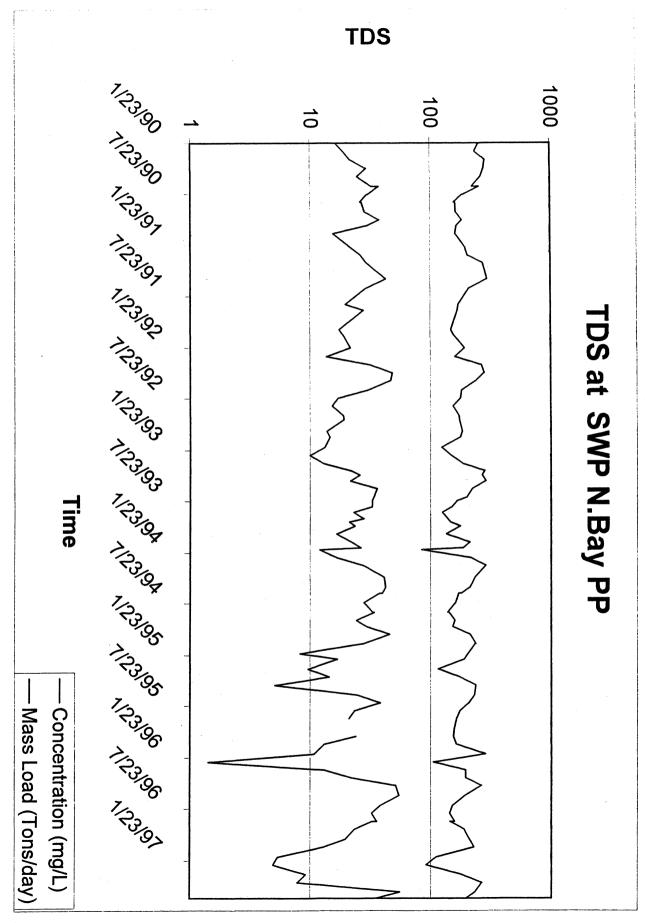
California Aqueduct, State Water Project

Historic TDS concentrations and loads at H.O. Banks Pumping Plant are shown in Figure 6-35, as measured by collection of discrete samples. No discernable long term trends of change are apparent. Figure 6-36 shows TDS concentrations in dry years are higher in all months. Elevated TDS loads, characterized by Figure 6-37, occur during the months of January through March, and again in the summer months of dry years. Referring to Figure 6-38, TDS concentrations are widely distributed, the majority being found in the range of 150 to 400 mg/L. TDS loads are also widely distributed, as indicated in Figure 6-39. The great majority of observations fall in the range of 0 to 4000 Tons/day, with excursions to greater than 7000 Tons/day.

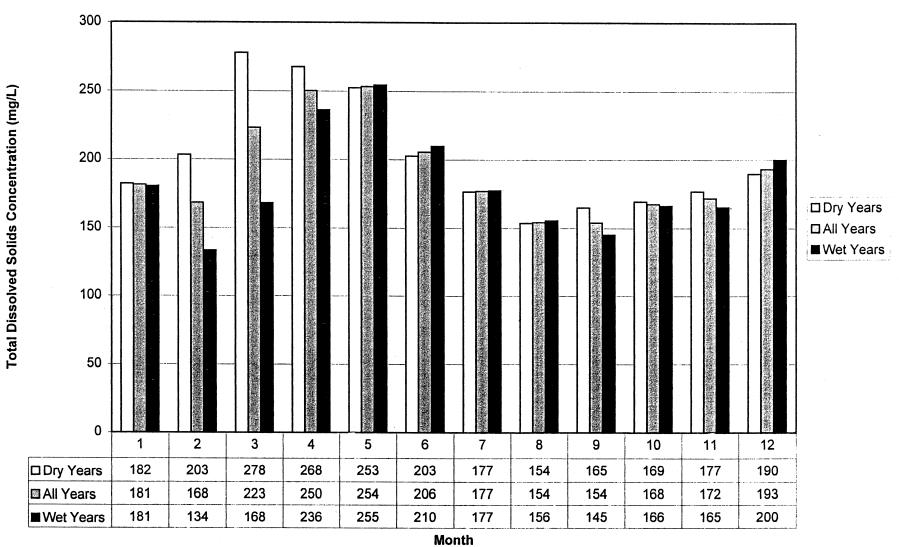
Figure 6-40 presents historical TDS inferred from continuous recordings of specific conductance (EC) at Banks Pumping Plant. Figure 6-41 and Figure 6-42 are frequency distributions of concentration and mass load based on continuous recorder data. These findings are comparable to those derived from collection and analysis of discrete samples.

Month





TDS at SWP North Bay PP



Month

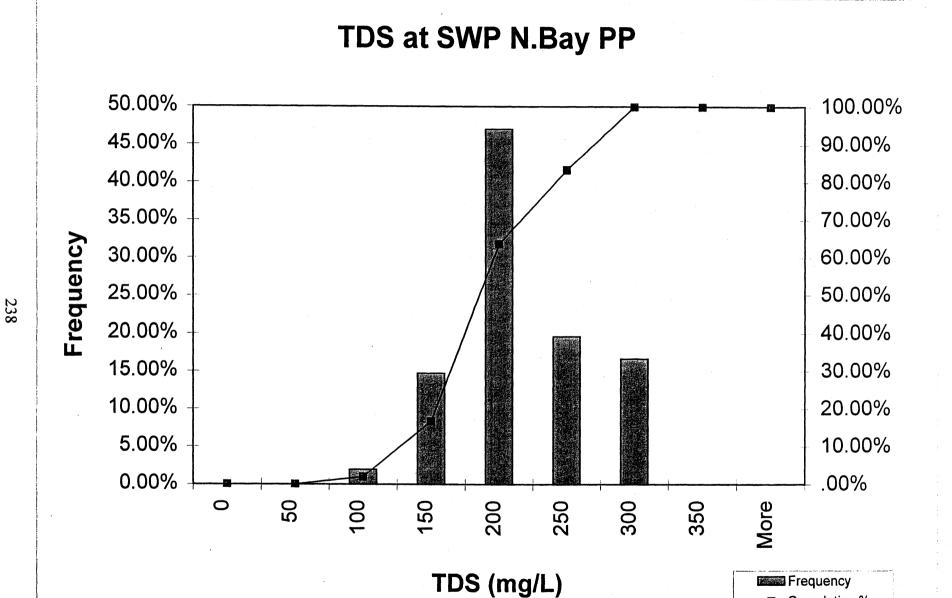
45.0

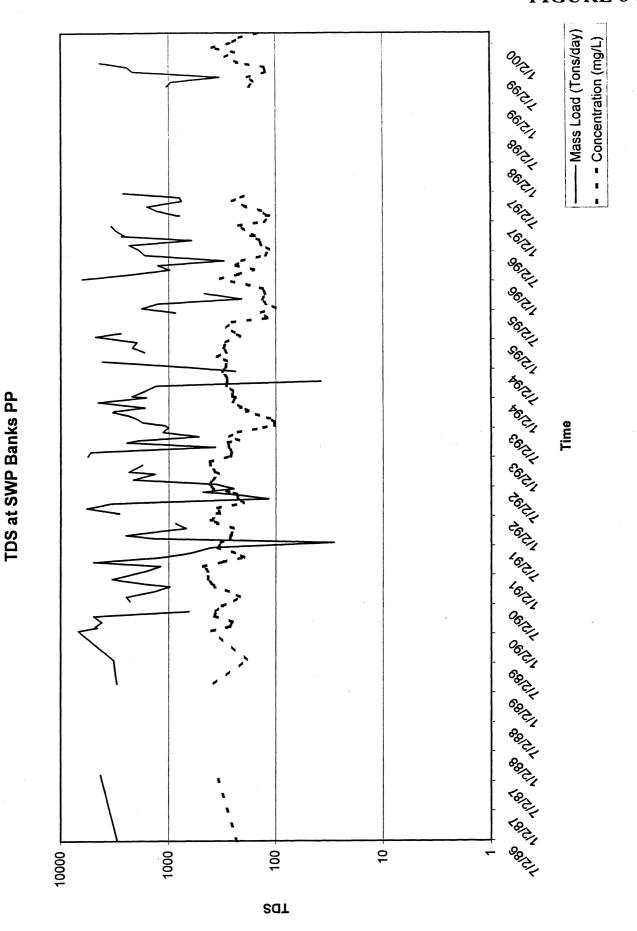
□ Dry Years

☐ All Years

■Wet Years

■- Cumulative %



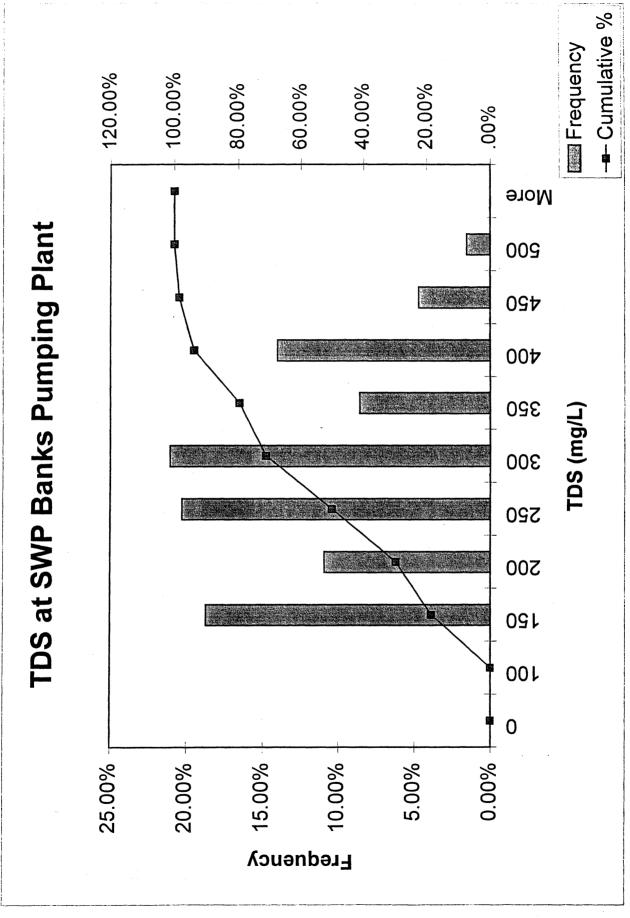


240

■Wet Years

Month

FIGURE 6-37



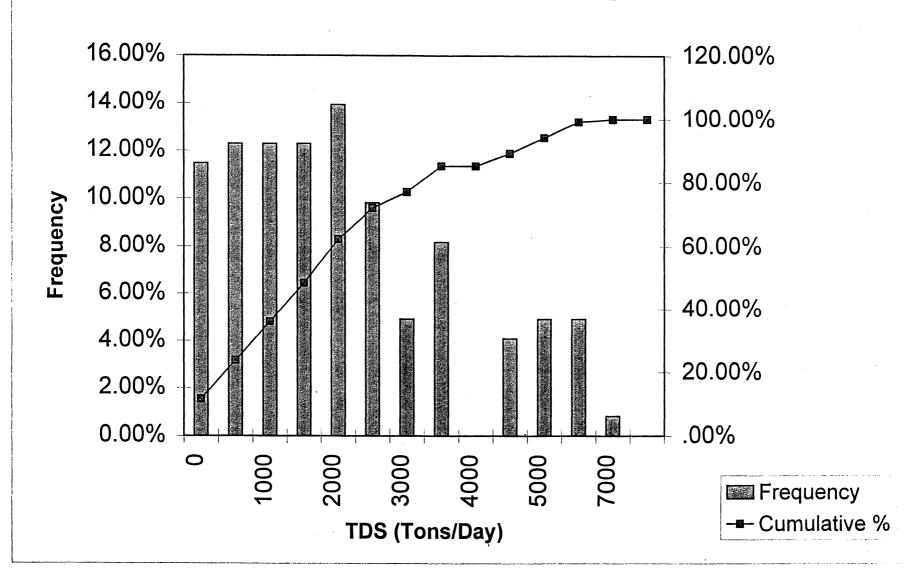
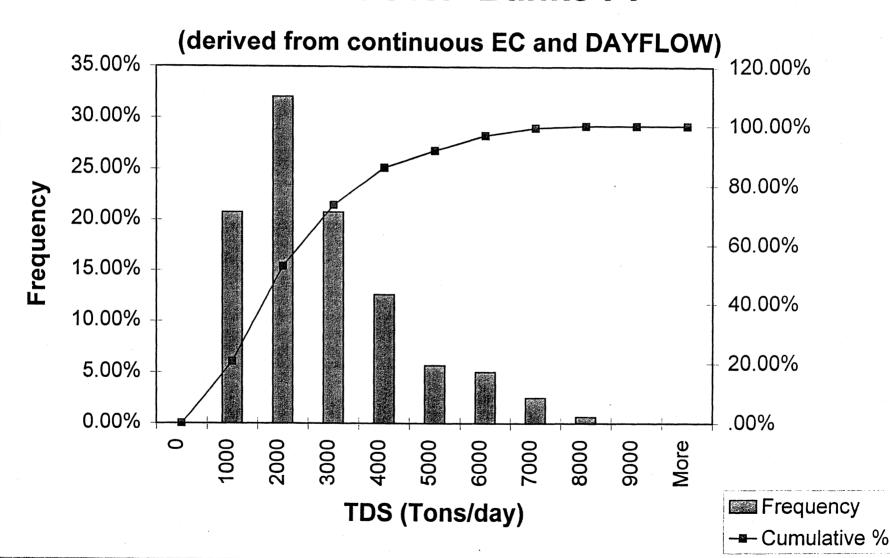


FIGURE 6-41

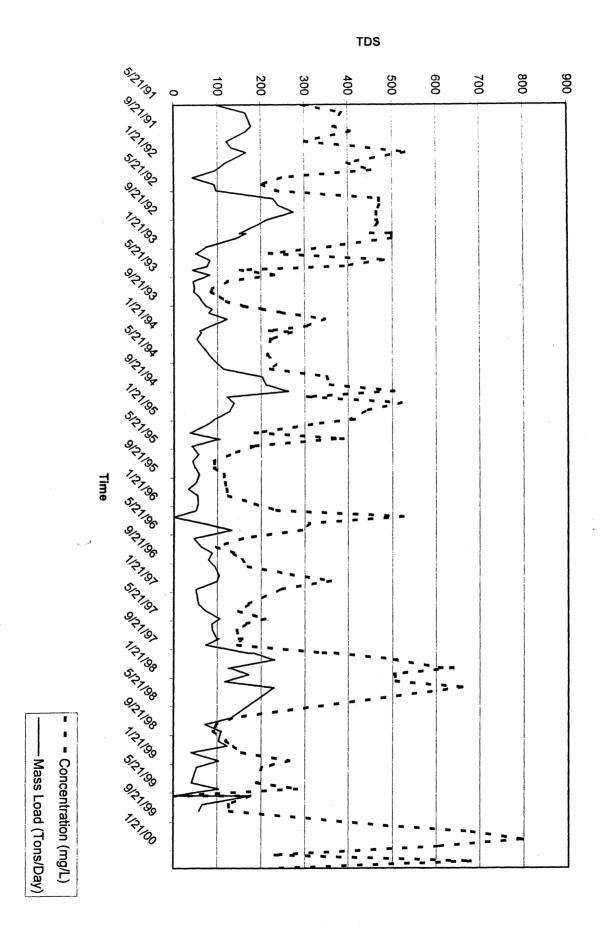


Contra Costa Water District Pumping Plant #1

Historical TDS conditions at Pumping Plant #1 are represented by Figure 6-43, which shows wide swings in TDS concentrations, almost certainly reflecting the more pronounced influence of sea water intrusion at this location as compared to the drinking water supply intakes further upstream (south) along Old River. The relatively small mass loads are a reflection of the smaller size of the system, as compared to the State and Federal diversions further south. Figure 6-44 shows that dry conditions cause elevated TDS concentrations in the summer months when fresh water flows are low. Wet conditions, conversely, enable sea water intrusion to be repelled with resulting good quality water in these months. As depicted in Figure 6-45, loadings of salt into the CCWD system are aggravated during dry years, especially in the summer months when concentrations are higher in dry years. Figure 6-46 shows concentrations are widely distributed, most falling in the range of 50 to 550 mg/L; Figure 6-47 demonstrates that most loadings fall in the range of 50 to 200 Tons/day.

Delta Mendota Canal, Central Valley Project

Figure 6-48 shows the historical record of TDS concentrations and loadings, as measured by the Department of Water Resources. The trend appears to be one of no significant change with time. Figure 6-49 shows that dry years are associated with elevated TDS concentrations in all months and that, in such years, December is highest. Loadings during wet months of dry years are high, while loadings during the warm months of wet years also tend to be high (Figure 6-50). The former observation is probably a reflection of poor salt dilution during winter months of dry years when San Joaquin River salt loads are high and contribute strongly to salinity of the DMC. The latter observation is probably a reflection of increased dilution due to more ample reservoir releases. Figure 6-51 indicates that most TDS concentrations measured at this location fall in the 200 to 500 mg/L range, and Figure 6-52 indicates most loads are in the range of 1000 to 4000 Tons/day.



TDS at CCWD PP #1

Month

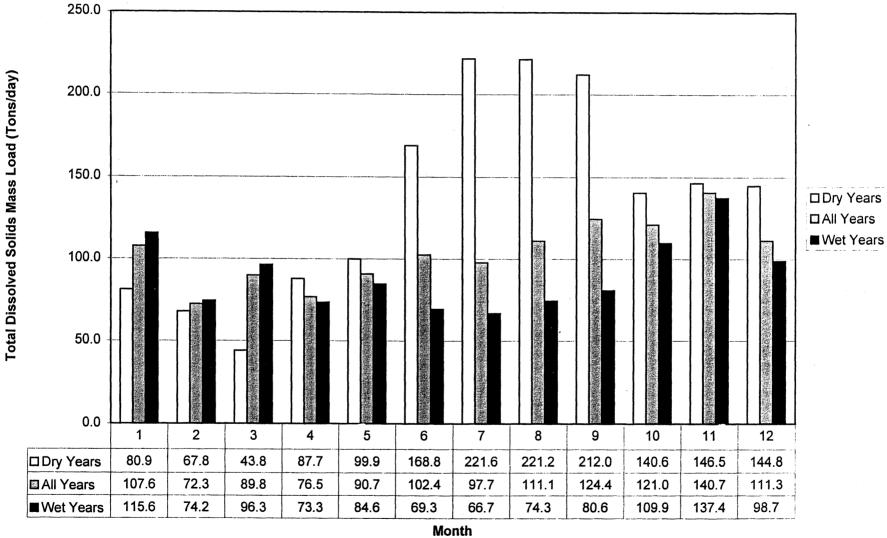
□ Dry Years

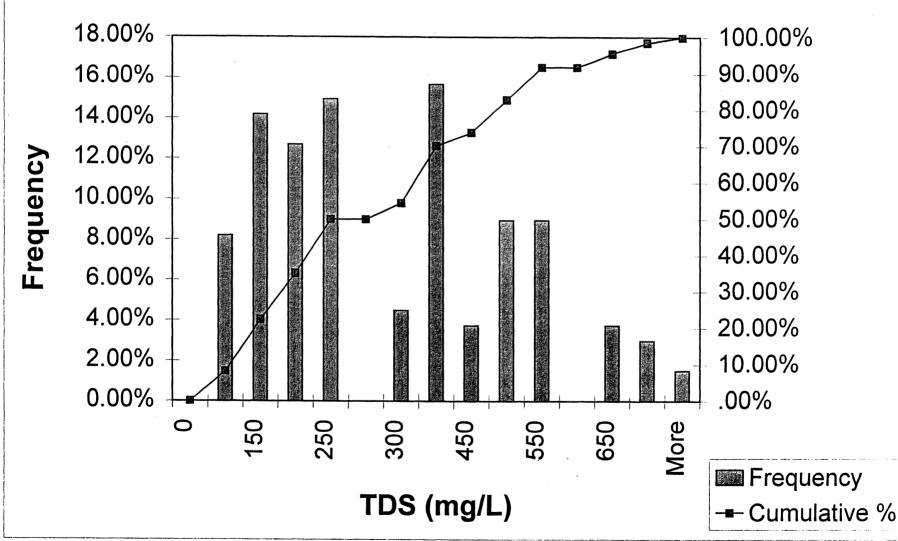
■ All Years

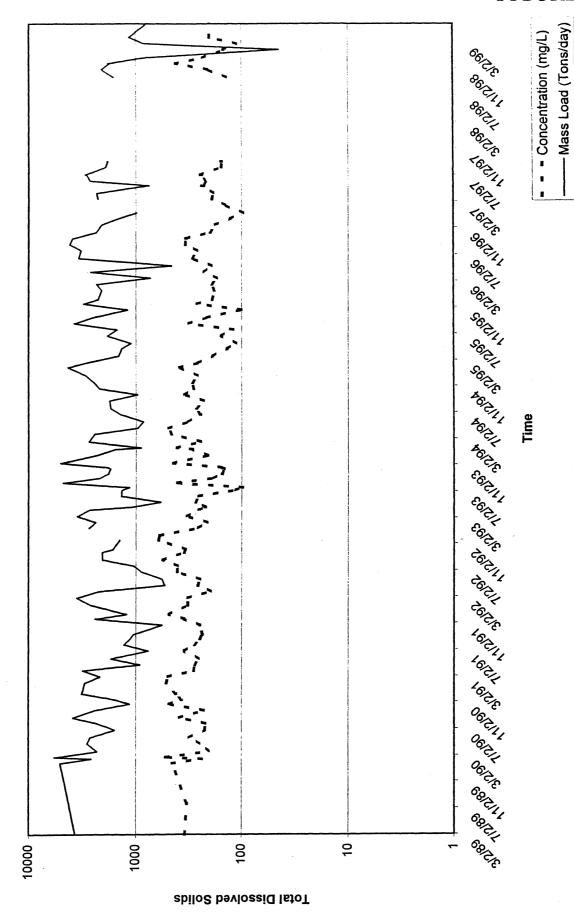
■Wet Years

□ Dry Years

☐ All Years ■ Wet Years





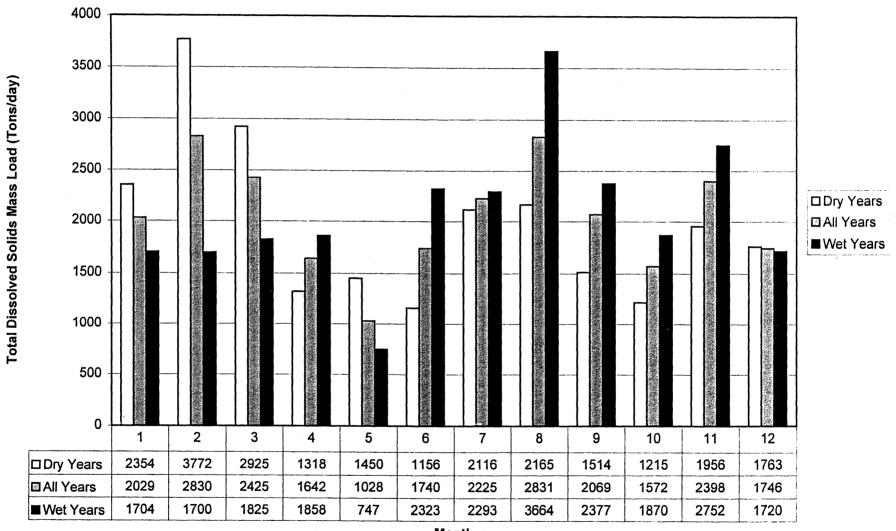


TDS at DMC Intake

254

Month

TDS at DMC Intake



Month

FIGURE 6-51

FIGURE 6-52

Turbidity

Turbidity is the physical characteristic of water that limits light penetration. It can be caused by inorganic particulate matter, such as sediment from erosion, and by organic matter such as algae and other life forms. Turbidity is important in drinking water because particulate matter has the capability to shield pathogenic organisms from the destructive effects of chemical oxidants used for drinking water disinfection. Cost of treatment can also be affected by turbidity as reflected in greater chemical use and increased volumes of waste solids that must be disposed. Another aspect of turbidity having significance to drinking water supplies taken from the Delta is its effect on the ability to monitor for the presence of pathogens in the source water. EPA Method 1623 is an assay for the presence of the protozoan pathogens Giardia lamblia and Cryptosporidium sp. The method, which involves filtration of water samples, is subject to interference by particulate matter in turbid waters, making difficult the task of assessing the pathogen status of Delta source waters. Decisions on the level of treatment required to achieve safe drinking water are, thus, made more complicated.

Figure 7-1 presents an overall perspective of turbidity in the Delta area. In general, the American River and the west side tributaries the Cosumnes and Mokelumne Rivers are characterized by low turbidity, whereas the waters of the Sacramento and San Joaquin Rivers are about seven times higher, overall.

The North Bay Aqueduct experiences the highest turbidities of the major drinking water diversions by a factor of two to three. This, like the elevated organic carbon found at this location is probably due largely to local watershed effects, and does demonstrate that agencies treating North Bay Aqueduct water are faced with special challenges.

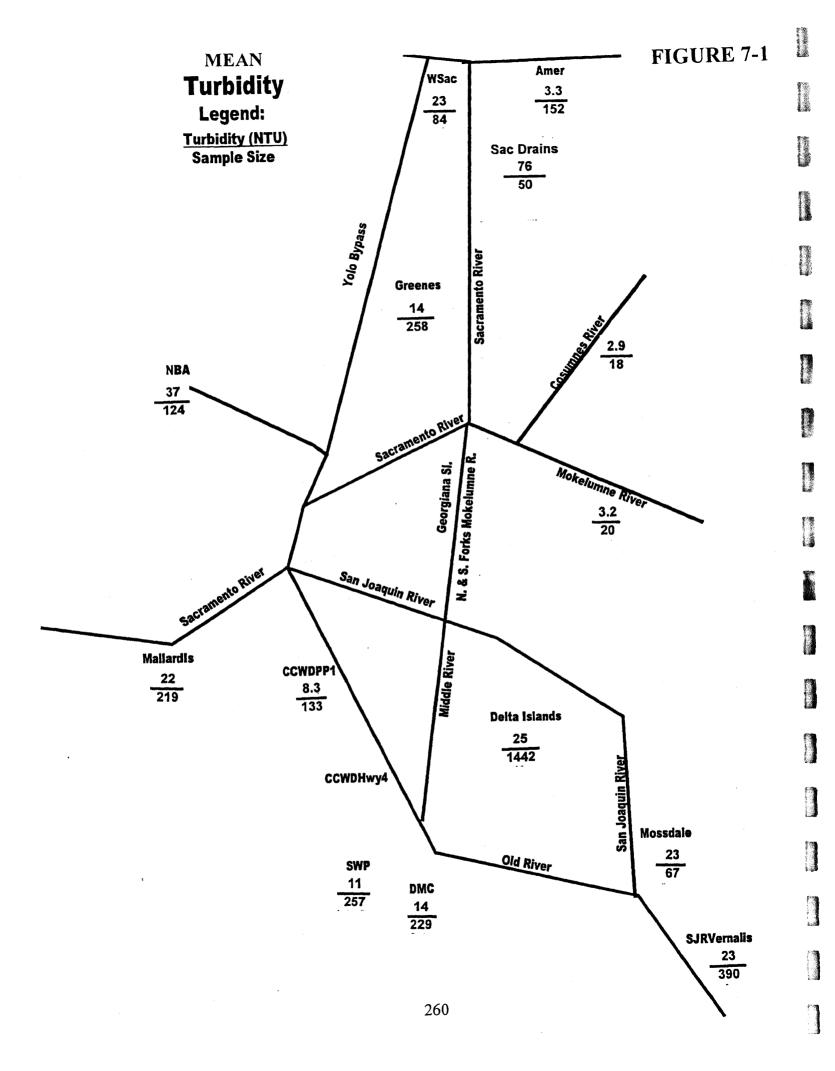
Drainage from Delta islands contributes a similar amount of turbidity as do the Sacramento and San Joaquin Rivers. The turbidity of Contra Costa's intake at Pumping Plant #1 is considerably lower than is found at the other drinking water supply intakes, perhaps due to settling as the water is transported out of Old River through Rock Slough to the pumping plant. Water taken into the State Water Project is about 20 percent lower in turbidity than water diverted into the Delta Mendota Canal (DMC). This is due to the fact that water flows through Clifton Court and settles there before being pumped into the California Aqueduct. On the other hand, the Tracy Pumping Plant takes water directly from Old River into the DMC, affording no opportunity for the river water to settle. The settling effect of Clifton Court can be seen in the need for periodic sediment removal from its bottom.

Delta Tributaries

The following describes turbidity conditions in the major inflows to the Delta.

Sacramento River

As the largest source of fresh water inflow to the Delta, turbidity in the river has important effects on the quality of waters diverted from the Delta for drinking water use.



West Sacramento Intake

Figure 7-2 depicts historical turbidity readings in the Sacramento River above its confluence with the American River, at the intake to the West Sacramento water treatment plant. Large swings are evident, most falling during wet periods when river flows were high (on the order of 70,000 cfs), indicating strong erosive forces in the watershed. An interesting, but unexplained, maximum was observed in December 1997 when river flow was only about 22,000 cfs, followed by a similarly high turbidity in February 1998 when flow was at about 67,000 cfs, more typically associated with such high turbidity.

Figure 7-3 presents computations of average monthly turbidities over different hydrologic year types. Consistent with the concept that mineral turbidity is caused by erosive flows, turbidities at this location are highest during wet seasons and wet years. Turbidity caused by algal growth would be expected to be reflected in increased turbidities during the warm months, and perhaps particularly during dry years when water clarities would improve light penetration for photosynthesis. Such a phenomenon appears not to be evident, however, suggesting that much of the turbidity found at this location is inorganic. The distribution of turbidity readings, presented in Figure 7-4, shows that most measurements fall within the 10 to 40 NTU range of turbidities.

Greenes Landing

Figure 7-5 displays historical turbidity readings taken in the Sacramento River at Greenes Landing. Peaks are associated with periods of high river flow. No long term trends of change are observed, however. Figure 7-6 presents the results of a linear regression analysis to examine the relationship between flow and turbidity at Greenes Landing. While there is a correspondence of higher flows with higher turbidities, the relationship is not very strong ($R^2 = 0.61$), indicating factors such as turbidity caused by algal growth may be at work.

Figure 7-7 shows monthly average turbidities over different hydrologies. Wet months, particularly during wet years, are associated with high turbidity. Absent is evidence of significant influence of algal growth during warm months. Figure 7-8 indicates that most measured values fall within a range of 10 to 30 NTU.

Mallard Island

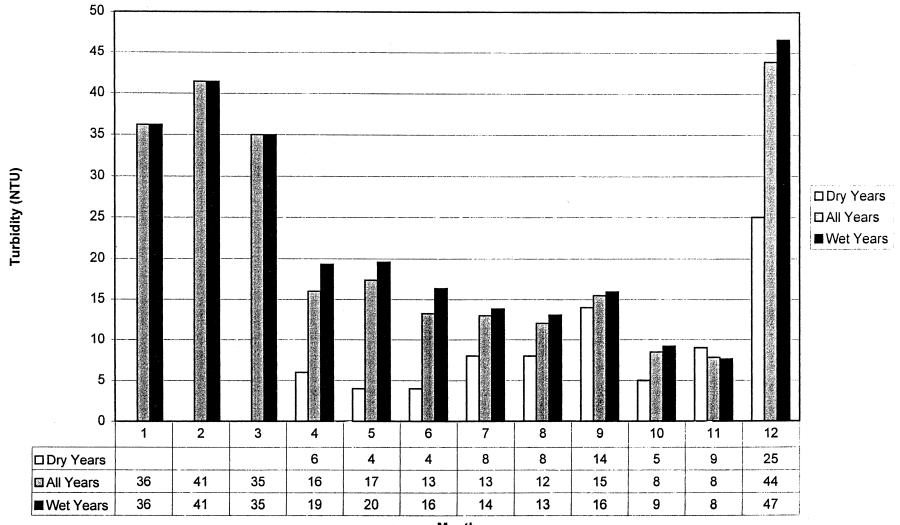
Figure 7-9 shows monthly average turbidities for the Sacramento at Mallard Island. Unlike the West Sacramento and Greenes Landing stations upstream on the Sacramento River, there is significant turbidity during the warm months of the year, particularly during wet years. And, while wet months, especially of wet years, are associated with maximum turbidities, the differences are not as pronounced as is the case upstream. This may be a reflection of increased turbidity caused by biological activity, and is consistent with knowledge that this area is important for supporting fisheries resources. As shown in Figure 7-10, about 80 percent of turbidity readings at this location fall in the range of 10 to 40 NTU.

00/61/1 66/61/01 66/6/x 66/6// 86/6/01 80/01/1 86/6/x 86/6// 10/01 16611 Time 1661/x 10/0/1/ 96/6/x 96/61/1 ·66/x S6/61/1 *6/6/01 20 6 20 9 8 30 8 2 9 Turbidity (NTU)

Turbidity of Sacramento R @ W.Sac. Intake

262

Turbidity of Sacramento R @ W. Sac. Intake



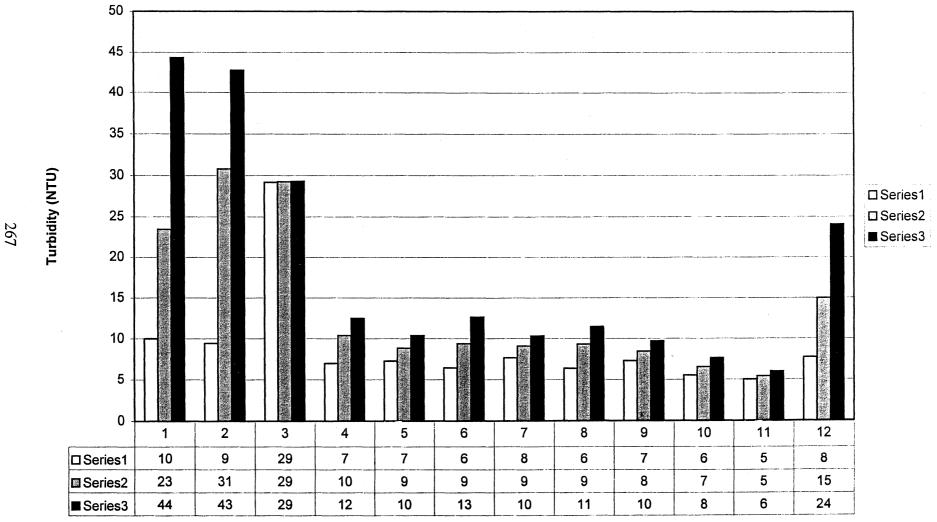
263

16/12/1 96/12/V 96/_{12/} Soldi AGIVEL . *6/Le/ COLON colon TO VOLV 16/12/ 16/12/1 06/12/ 06/12/1 68/12/ 69/2/1 80/12/ 80/12/1 10/1/10/1 10/12/ 80/12/V 98/12/1 *8/12/₁ 20 0 4 120 100 8 9 Turbidity (NTU)

Turbidity in Sacramento R @ Greenes Ldg.

265

Turbidity of Sacramento R @ Greenes Landing



Turbidity of Sacramento R @ Mallard Is

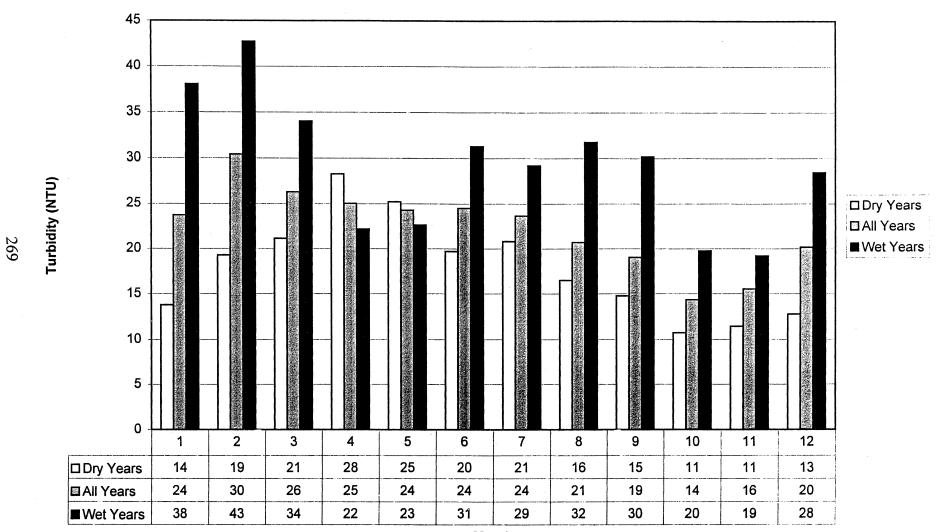


FIGURE 7-10

San Joaquin River

Turbidity observed in the San Joaquin River near Vernalis is used to represent inputs from that river.

Figure 7-11 presents historical turbidity records from the San Joaquin River near Vernalis. Large peaks occurred in February 1993 and February 1998. On the former occasion river flow was about 2900 cfs, which is low, but not unusually so. On the latter occasion, flow was about 20,000 cfs. Flows as high as about 33,000 cfs were observed during the period of record, and turbidities during these times were lower. So, these observations are not explained on the basis of the relationship between flow and turbidity.

Figure 7-12 shows monthly averages, and indicates that February is a peak period for turbidity, and more so in that month of wet years. Turbidity observed during that period is consistent with mineral turbidity caused by erosive forces. During the warm months, a different pattern emerges. July of dry years is associated with highest turbidities, and turbidity rises from April through a peak in July, and recedes by fall of the year. This observation could be explained by algal growth, and such an hypothesis is supported by the observation, discussed in the nutrient section of this report, that total nitrogen and total phosphorus concentrations at this location are three times higher than are found in the Sacramento River at Greenes Landing. Most turbidity measurements made at this location fall within the 10 to 40 NTU range, as depicted in Figure 7-13.

American River

Figure 7-14 is a presentation of historical turbidity data collected in samples of the American River at the intake to the Sacramento water treatment plant. A pronounced peak occurred in February 1986 during the historically high flows present at that time. No long term trends of change are apparent. Monthly averages, presented Figure 7-15, indicate that turbidities in most months are low, and that wet periods, especially in wet years, are important contributors of turbidity. The lack of turbidity at times other than when flows are high is an indication of minimal algal production, suggesting the turbidity at this location is mostly from mineral particulates. Most turbidity readings taken at this location fall in the 2 to 4 NTU range, as depicted in Figure 7-16.

Discharges

Turbidity data have been found for drainage from Sacramento storm drainage and Delta islands. Data for other waste water and storm water discharges were not available.

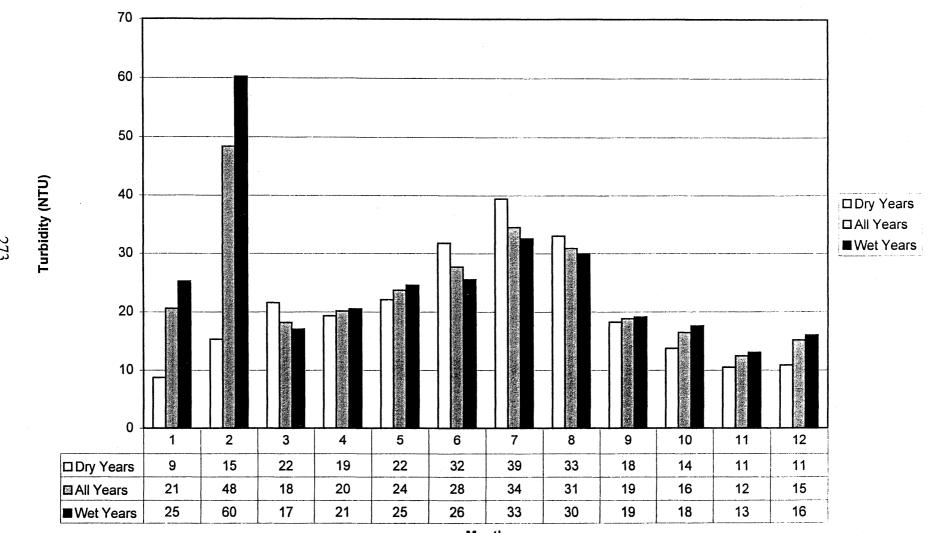
Sacramento Storm Drainage

Based on 50 storm drain samples collected from six Sacramento area locations over the period October 1991 through February 1992, the average turbidity in Sacramento storm drain samples was 76 NTU, with a standard deviation of 83 NTU.

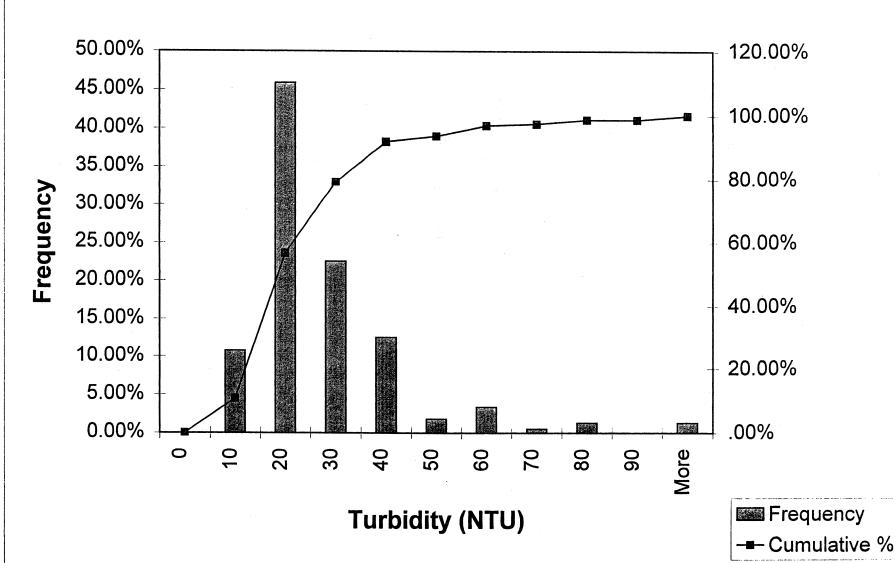
Time Turbidity (NTU)

Turbidity in S.J.R. nr. Vernalis

Turbidity in S.J.R. nr. Vernalis



Turbidity in S.J.R. nr. Vernalis



Turbidity in American R @ WTP

Turbidity (NTU)

Turbidity in American R @ WTP

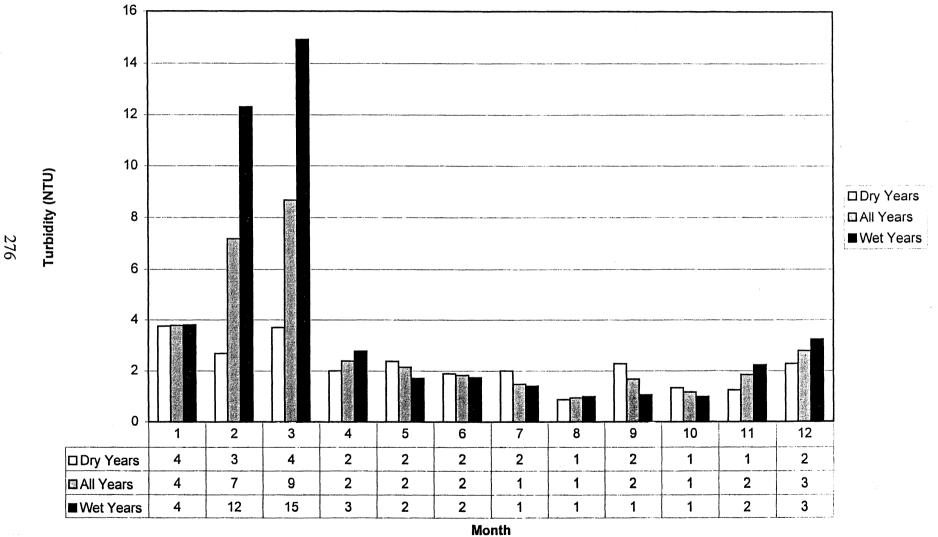
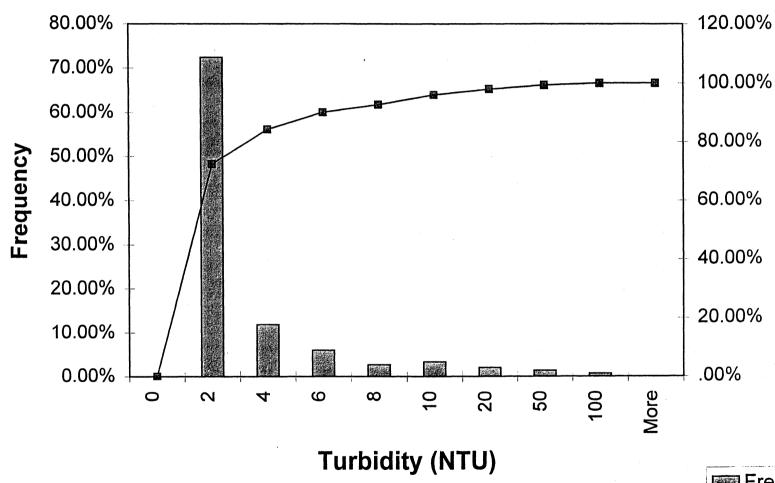


FIGURE 7-15



Frequency

--- Cumulative %

Delta Island Drainage

Figure 7-17 demonstrates that turbidity in drainage from Delta islands does not vary greatly by month or by hydrologic year type, except that during wet years, February and June are associated with high turbidities. The February peak could reflect seasonal discharge of water used to leach island soils and the June peak may reflect discharge of residual irrigation water.

Diversions

Turbidity is measured in water diverted for use as drinking water supply. The results are discussed here.

North Bay Aqueduct, State Water Project

Historical turbidity measurements made at the North Bay Pumping Plant intake to the North Bay Aqueduct are depicted in Figure 7-18. The location is characterized by wide turbidity swings, which fosters appreciation of the difficulties encountered by agencies treating the water from this source. Treatment processes generally operate best under constant conditions. When water quality undergoes rapid and pronounced changes, such as is the case with turbidity at this location, treatment systems must be continually rebalanced to provide optimum drinking water quality. This greatly complicates the challenge of providing consistently high quality treated drinking water.

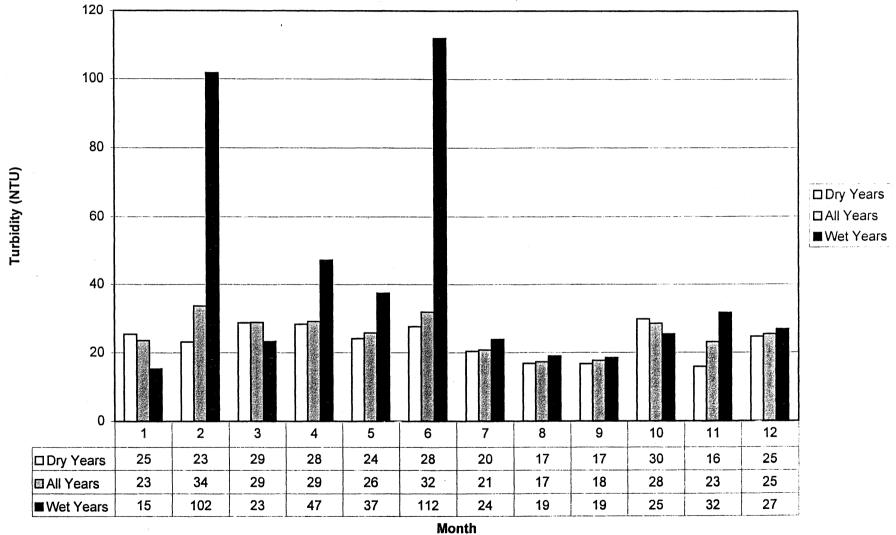
Figure 7-19 provides an indication that erosive effects in the watershed are important for producing turbidity, as is seen in peaks during wet months, particularly during wet years. The turbidity peak observed in June and July irrespective of hydrologic conditions appears to provide evidence of algal productivity during the warm months. Turbidity makeup may, therefore, change from mineral in the winter more toward organic in the summer. Figure 7-20 reveals that frequency of turbidities is not sharply defined, with turbidities over the wide range from 10 to 100 NTU comprising about 80 percent of observations. Very high turbidities are sometimes observed, suggesting that the North Bay Aqueduct is heavily exposed to localized effects from the watershed.

California Aqueduct, State Water Project

Figure 7-21 summarizes historical turbidity readings made on samples collected at the H.O. Banks Pumping Plant in the south Delta. Turbidity swings of 30 NTU have been experienced, with peaks generally appearing during the months of June and July. No obvious longer-term trends of change are noted. Figure 7-22 reflects the effects of settling in Clifton Court, the forebay to the pumping plant. Whereas other locations experience pronounced turbidity peaks during the wet months, such peaks are not observed at the pumping plant. This figure also suggests that algal productivity, perhaps produced in part in Clifton Court, may affect turbidity during the warm months. The pattern of higher turbidities in the warm months of wet years may be a reflection of turbidity caused by increased channel velocities from pumping.

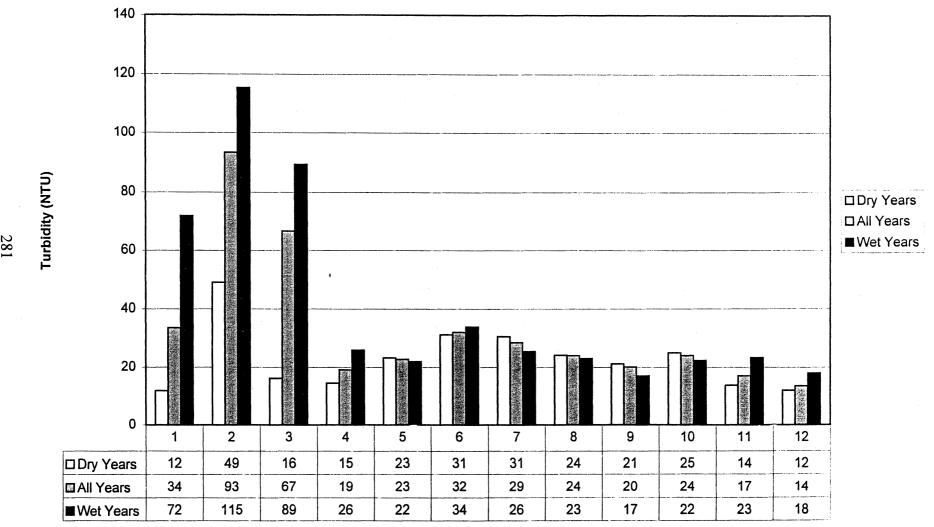
Most measured turbidities at this location are in the 5 to 20 NTU range, which is also a reflection of the beneficial effect of Clifton Court (Figure 7-23). Comparison of this figure to the equivalent figure for the DMC Intake indicates the range of 10 to 25 NTU is most commonly observed at the latter location that does not have the benefit of a forebay.

Turbidity in Delta Island Drains



Turbidity at SWP N. Bay PP

Turbidity at SWP North Bay PP



Turbidity at SWP N. Bay PP

120.00%

100.00%

80.00%

60.00%

40.00%

20.00%



Frequency

25.00%

20.00%

15.00%

10.00%

5.00%

S Turbidity (NTU)

Turbidity at SWP Banks PP

Contra Costa Water District Pumping Plant #1

Historical turbidity at Contra Costa Water District's Pumping Plant #1 is shown in Figure 7-24. Figure 7-25 shows that turbidities reach maxima during warm months of wet years. During dry years, turbidity is generally low in these months. Algal productivity may play a role during these months. Another factor may be the effect of higher pumping rates during the warm months of wet years causing increased channel velocities and transport of particulate matter. Wet months are not associated with elevated turbidities, suggesting settling in Rock Slough as a possible factor. Figure 7-26 indicates the most frequently observed turbidities are found in the 2 to 12 NTU range, lower than is commonly found at the other diversions.

Delta Mendota Canal, Central Valley Project

Figure 7-27 depicts the record of turbidity compiled by the Department of Water Resources in the Delta Mendota Canal just downstream of Tracy Pumping Plant. Peaks were observed during January 1995 and January 1997 during high flow conditions. No long term patterns of change are obvious. Turbidity observations averaged by month appear in Figure 7-28. January of wet years is associated with high turbidity; but, this average will have been strongly affected by the peaks experienced in January of 1995 and 1997. The pattern of increasing turbidity during warm months may reflect a combination of seasonal algal growth and turbidity induced by pumping. Figure 7-29 demonstrates the most frequently observed range of turbidities is 10 to 25 NTU.

0000 16₀01 10₀ color E6/2/9 161/01/09 101/01/09 26/1/2 1000 Tello Tello Cello Ö 2 25 15 9 20 30 Turbidity (NTU)

Turbidity at CCWD PP #1

Turbidity at CCWD PP #1

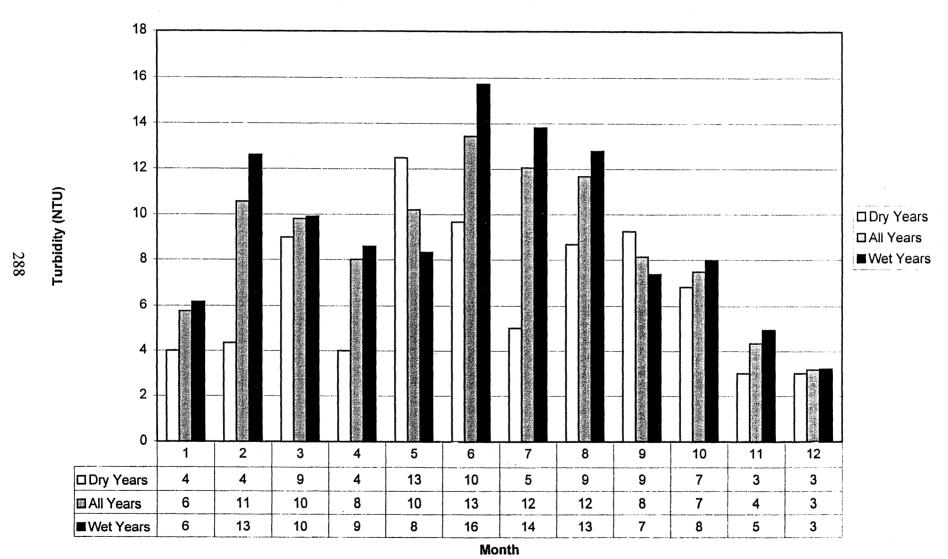
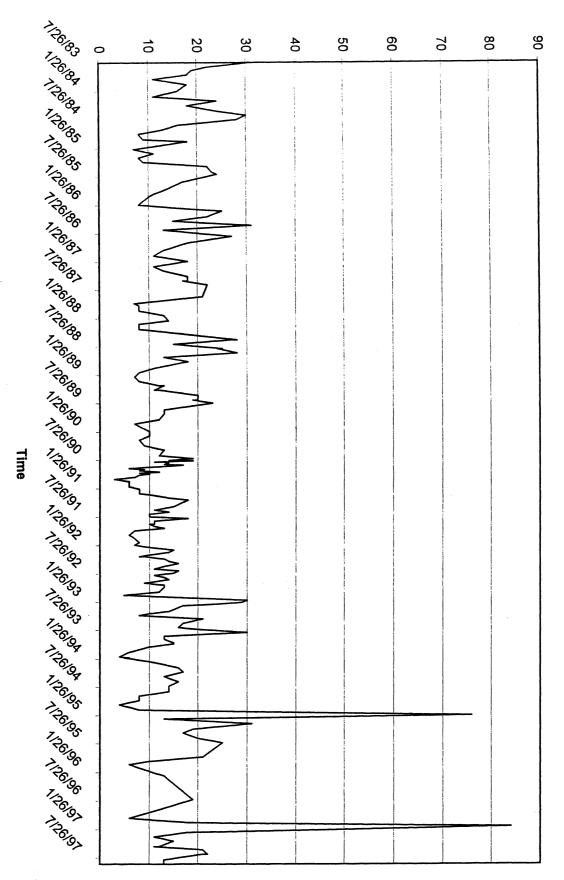


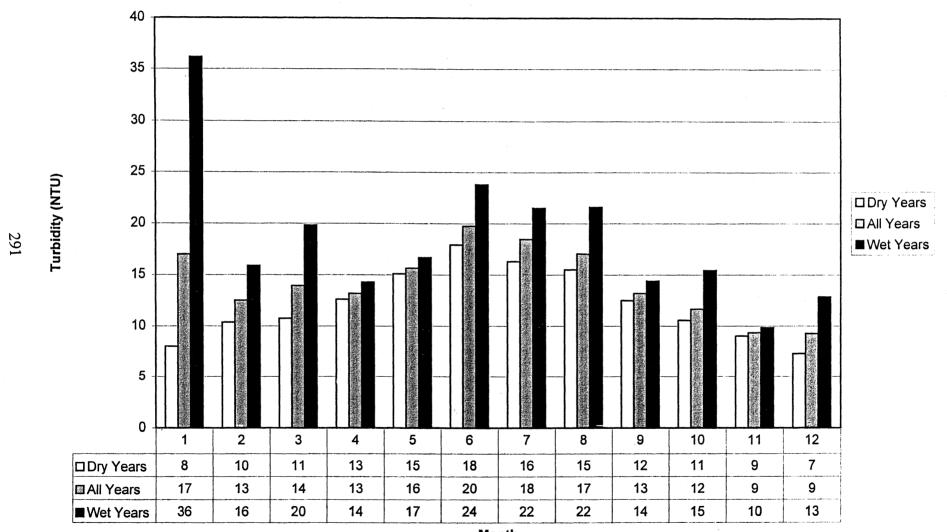
FIGURE 7-25

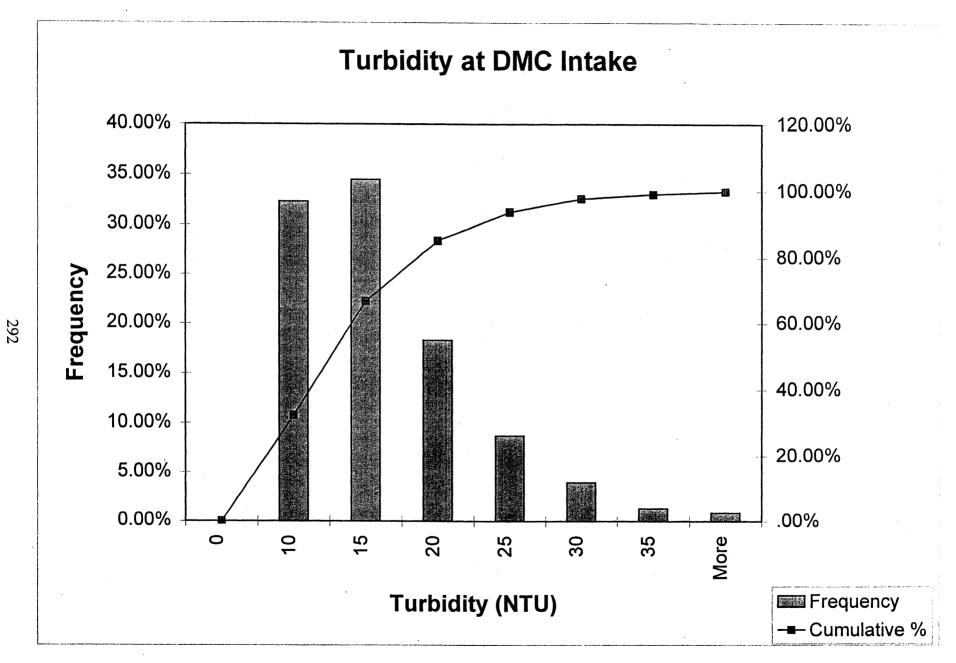
Turbidity (NTU)



Turbidity at DMC Intake

Turbidity at DMC Intake





Nutrients

Nutrients were identified by the Drinking Water Constituents Work Group as being of concern to drinking water and, therefore, in need of addressing in this study.

The nutrients that are generally most important to primary productivity (algal growth) in Delta channels are forms of nitrogen and phosphorus; however, algae growth in the Delta is often limited by light penetration, due to the usual turbidity of Delta waters. For most algal forms, nitrate is the most biologically available of the nitrogen compounds, while ortho-phosphate is typically the most biologically active phosphorus compound. Biological activity and natural oxidative and reductive processes cause nitrogen and phosphorus compounds to transform from one state to another, so nutrients are not conservative in the system as are salts. Nitrogen is also lost from the system as gaseous nitrogen, and added to the system by fixation of gaseous nitrogen by some terrestrial plants, and by some algae.

As a general rule, algae incorporate nitrogen and phosphorus in approximately a 16:1 ratio, on an atomic basis. When dissolved ortho-phosphorus concentrations are above about 5 ug/L, there is an excess of phosphorus relative to algal requirements; whereas, when dissolved nitrate concentrations exceed about 20 ug/L, there is generally an excess of nitrogen relative to algal needs. In the absence of other limiting factors, algal growth will be limited by whichever nutrient is in shortest supply, relative to algal requirements./6 However, in the Delta, limited light penetration caused by the usual turbidity and color of Delta waters often limits algal growth such that both nitrogen and phosphorus concentrations found in Delta waters often exceed those required to support additional growths.

Algal growths supported by the nitrogen and phosphorus nutrients produce organic carbon that may, under certain conditions, enhance production of disinfection byproducts in drinking water. Also, some algae produce compounds capable of imparting unpleasant odors and flavors to drinking water. These tastes and odors can be very difficult to control, and can require greatly increased usage of treatment chemicals, with associated increased solid waste from treatment processes. Algae can also clog filters and other water conveyance and treatment equipment. Due to these problems, waters low in nutrients are more desirable as drinking water sources.

By contrast, the standing crop of algae forms the basis for the food web that supports invertebrate and vertebrate forms of animal life, including fish. For many species that inhabit the Delta, it may be true that more, rather than less, nutrients are advantageous. Thus, the need for nutrients to support a healthy ecological system in the Delta can be at odds with the need to minimize nutrient presence in sources of drinking water. Reaching an optimal balance is one of the challenges facing the CALFED Program.

Data exist for nitrate and ortho-phosphate in Delta waters. Other nitrogen compounds for which data exist include ammonia, nitrite, and organic nitrogen. Other phosphorus compounds for which data exist include acid hydrolyzable phosphate, and total phosphorus. Data also exist for total nitrogen and total phosphorus.

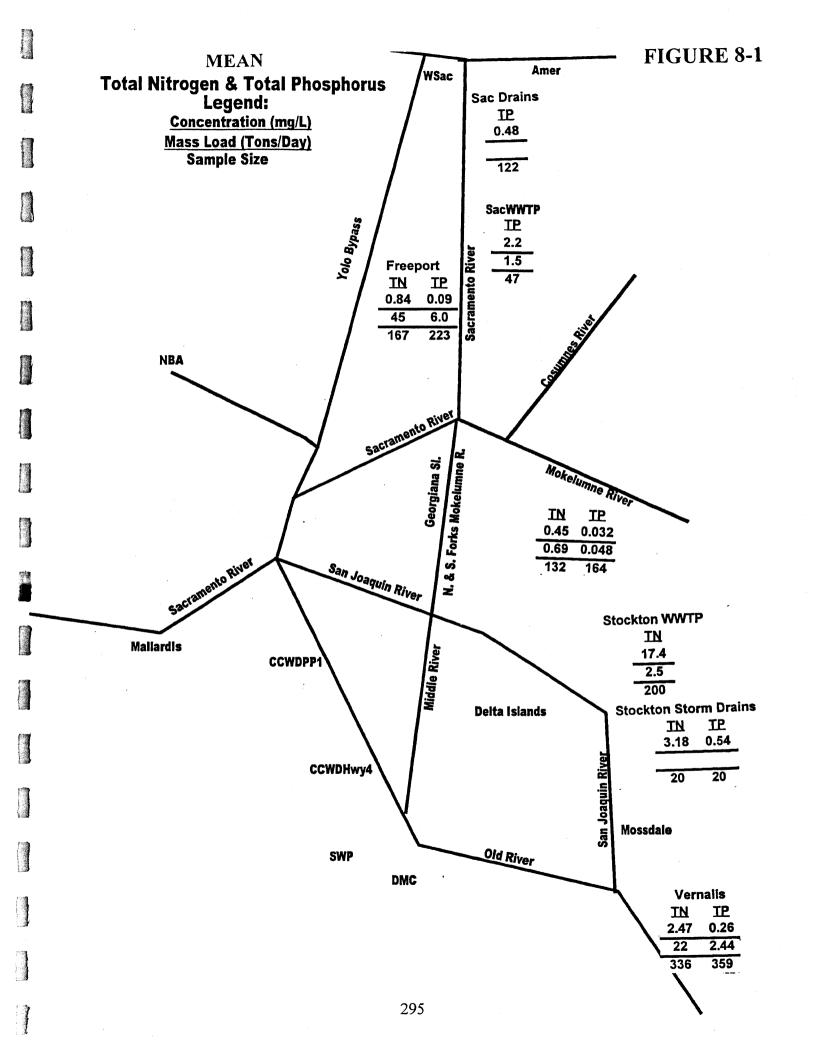
Examination of nutrient data for individual chemical species generally does not provide a clear picture of the capacity for algal growth because of the continual change in the composition of the nitrogen and phosphorus compounds, and because algae will respond to increases in nutrient availability only when nutrient availability is limiting growth. As previously discussed, algal growth in the Delta is often limited by turbidity and color of the water.

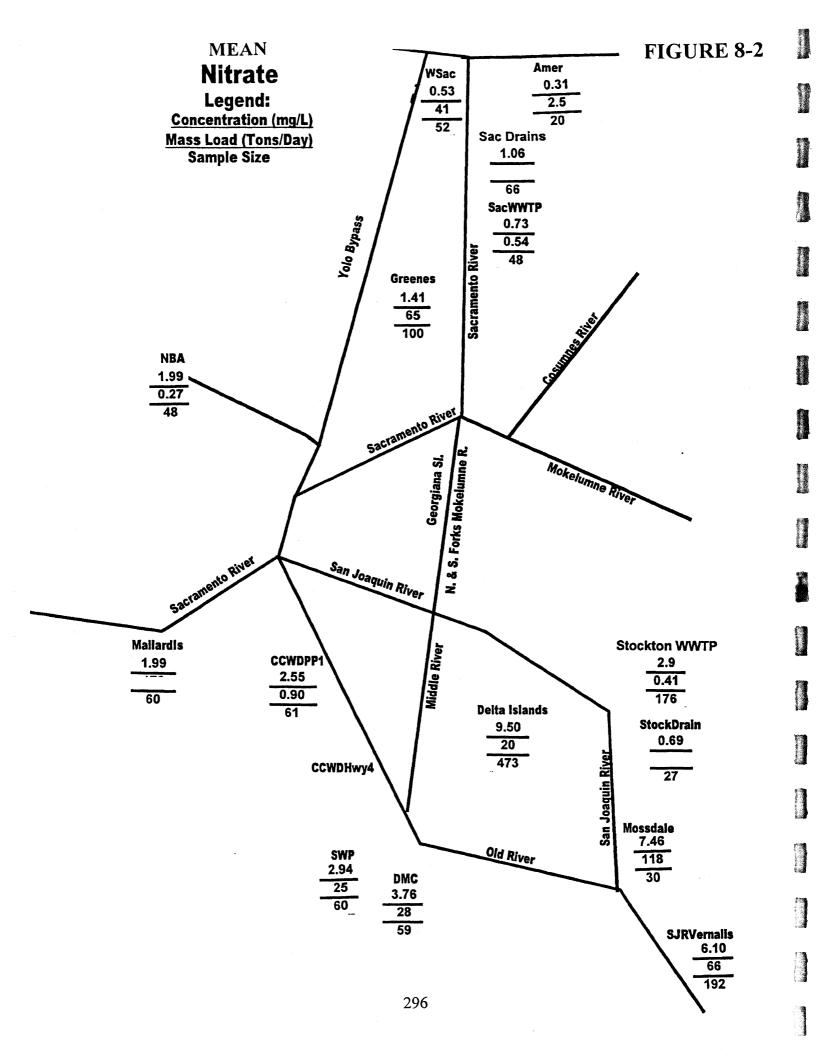
Despite the difficulty of interpreting the data, it is perhaps useful to examine nitrate and ortho-phosphate data to get an overall idea of nutrient availability to algae. This may help to provide an understanding of algal growth patterns.

Nutrient data on Delta waterways reviewed in this study were from The Department of Water Resources and from the U.S. Geological Survey. The Department of Water Resources Municipal Water Quality Investigations Program has rather extensive data on nitrate, and some data on total phosphorus. The U.S. Geological Survey collects extensive nutrient data on the Sacramento River at Freeport and on the San Joaquin River near Vernalis. Because the USGS data set is rather complete for the Freeport and Vernalis locations, more extensive effort is devoted to reviewing the data for the various species of nitrogen and phosphorus at these two locations. As these are the primary tributaries to the Delta, this should provide a good indication of overall nutrient supplies to the Delta through the inflow streams.

Figure 8-1 presents overall concentrations and loadings of total nitrogen and total phosphorus, as measured by the USGS at its Freeport, Vernalis and Mokelumne River monitoring stations, and from measurements of storm drainage concentrations by the cities of Sacramento and Stockton. Data from Sacramento Regional County Sanitation District and Stockton Waste Water Treatment Plant are also summarized. The Sacramento River and its tributaries account for twice the load of total nitrogen compared to the San Joaquin River, and about two and one-half times the phosphorus load. Concentrations of total nitrogen are, however, nearly three times as large in the San Joaquin as in the Sacramento, and total phosphorus loads are also nearly three times larger. These data reflect the poorer quality and lower flows of the San Joaquin River as compared to the Sacramento River, an observation that is common to a number of water quality constituents. Concentrations of nitrogen and phosphorus in Stockton storm drainage are higher than in the San Joaquin River; however, no flow estimates are available to enable computation of loads. The Mokelumne River does not contribute significantly to either concentrations or loads of nitrate entering the Delta.

Figure 8-2 is a summary of nitrate concentrations and loads at various locations as measured by the Department of Water Resources, cities of Sacramento and of Stockton (in storm drainage) and by Sacramento County Regional Sanitation District and City of Stockton in (treated waste water effluent). Despite its smaller size, the San Joaquin River contributes a nitrate load similar to that of the Sacramento River, with concentrations over four times higher than are present at Greenes Landing. The influence of the San Joaquin River and Delta island drainage is evident in nitrate concentrations found at the





south Delta points of diversion of drinking water supplies, which are roughly twice the concentration as is found in the Sacramento River. The North Bay Aqueduct also experiences higher nitrate concentrations than the Sacramento River at Greenes Landing, probably due to the influence of the local watershed.

Appendix A contains an analysis of available nitrate data, collected by the Department of Water Resources, that is not discussed in detail here.

A more complete discussion of nutrients in the Sacramento River at Freeport and in the San Joaquin River near Vernalis, as measured by the U.S. Geological Survey, follows.

Sacramento River at Freeport

Figure 8-3 summarizes historical total nitrogen concentrations and mass loads in the Sacramento River at the Freeport Bridge, just upstream of the discharge of the Sacramento County Regional Sanitation District. These data are based on 167 samples collected over the period of record. The pronounced concentration and load spike observed in September 1976 is not explained, other than the fact that historic drought conditions were being experienced at that time, and flow was just over 13,000 cfs, which is low. Later that year flows were even smaller, though, and were not accompanied by such high nitrogen concentrations. Otherwise, no obvious trends of change are noted. Figure 8-4 depicts total nitrogen concentrations by month over various hydrologic conditions. The high reading in September 1976 has distorted the average. Loadings of total nitrogen, represented by Figure 8-5 show that wet months of wet years are typically associated with highest loadings.

The frequency distributions for concentrations and loadings show that most total nitrogen concentrations observed fall within a 0.4 to 1.0 mg/L range, while most loads are within the range of 10 to 50 Tons/day. (Please refer to Figure 8-6 and Figure 8-7.)

Ammonia, as shown in Figure 8-8 is highest in January of dry years; whereas Figure 8-9 demonstrates that wet months of wet years are associated with highest loads, and wet years in general are associated with larger ammonia loads.

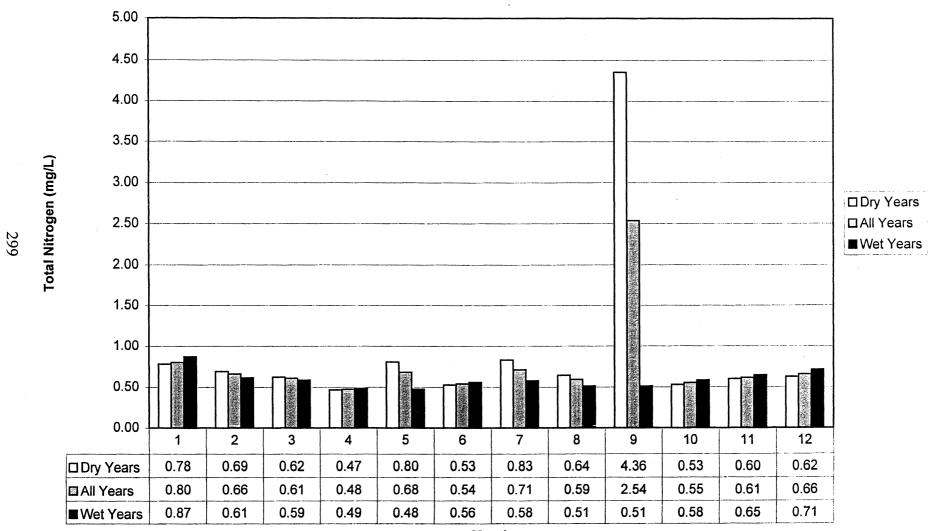
Nitrite is depicted in Figure 8-10, indicating that dry years are generally associated with higher nitrite concentrations in most months, while May of wet years has seen the highest concentrations. Figure 8-11 shows that, like ammonia, nitrite loads are highest in wet months of wet years, and higher in wet years generally.

Nitrate is summarized in Figure 8-12. Wet month of wet years produce somewhat higher concentrations, and based on Figure 8-13, significantly higher loads of nitrate, although hydrologic year type appears to be a less important determinant of nitrate concentration.

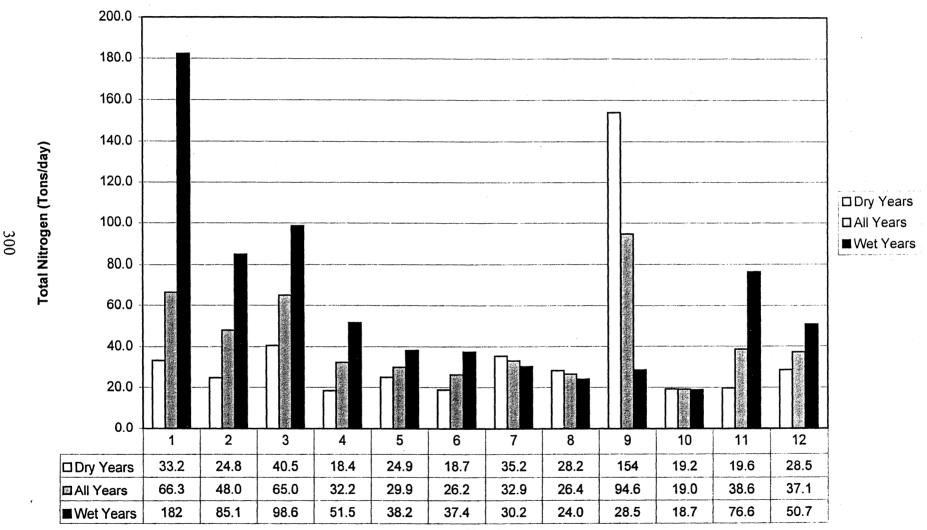
Kjeldahl nitrogen is a measure of organic nitrogen and ammonia taken together. As depicted in Figure 8-14, dry years, and especially dry months of dry years, produce highest concentrations. This may be due to greater incorporation of nitrogen into organic forms, and/or from a greater presence of ammonia. Referring to the ammonia graph,

Time

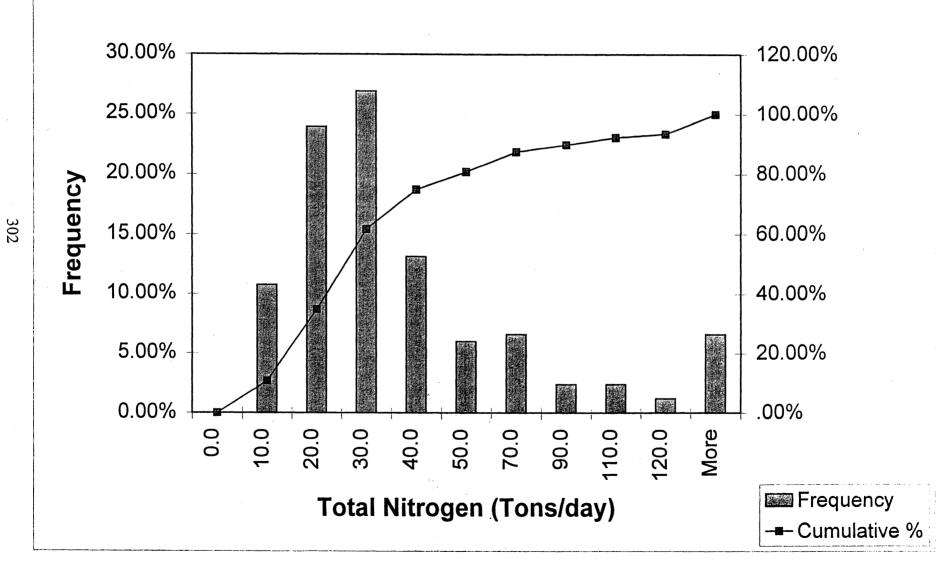
Total Nitrogen in Sacramento R @ Freeport



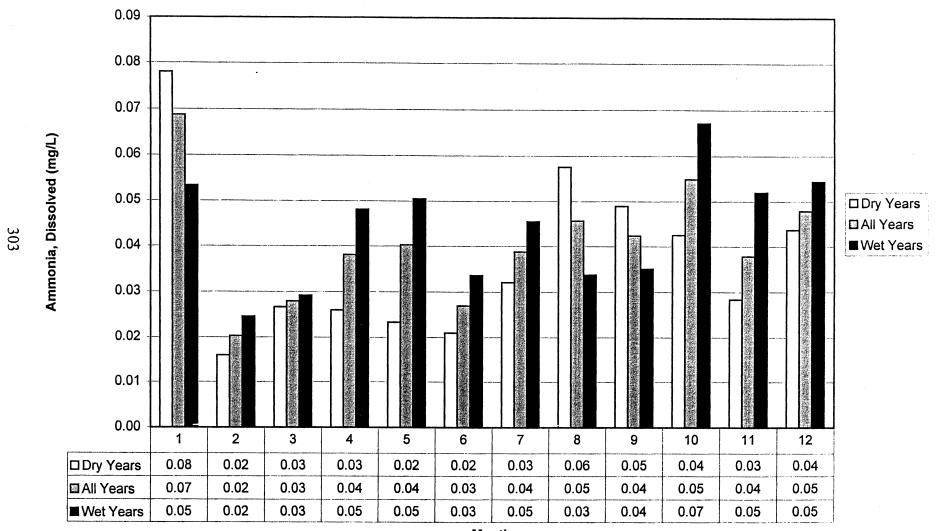
Total Nitrogen in Sacramento R @ Freeport



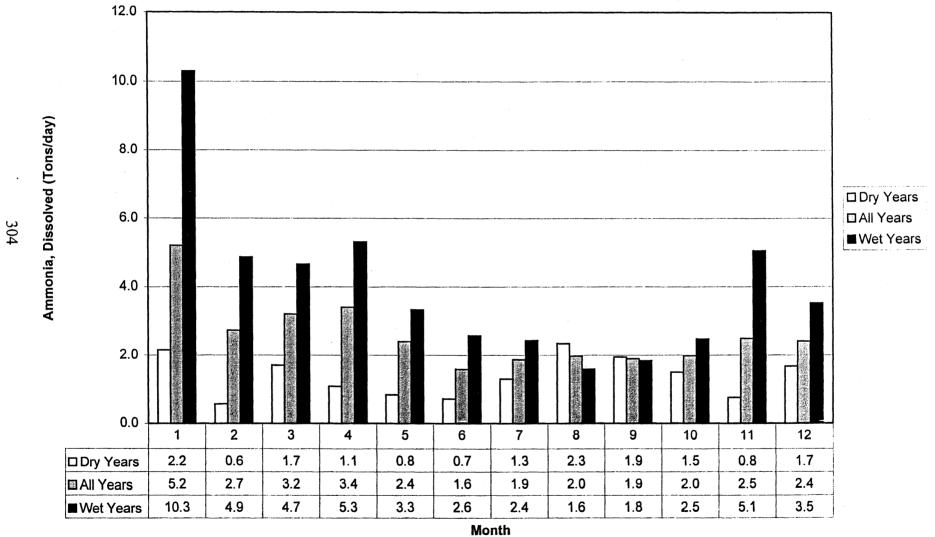
Total Nitrogen in Sacramento R. @ Freeport



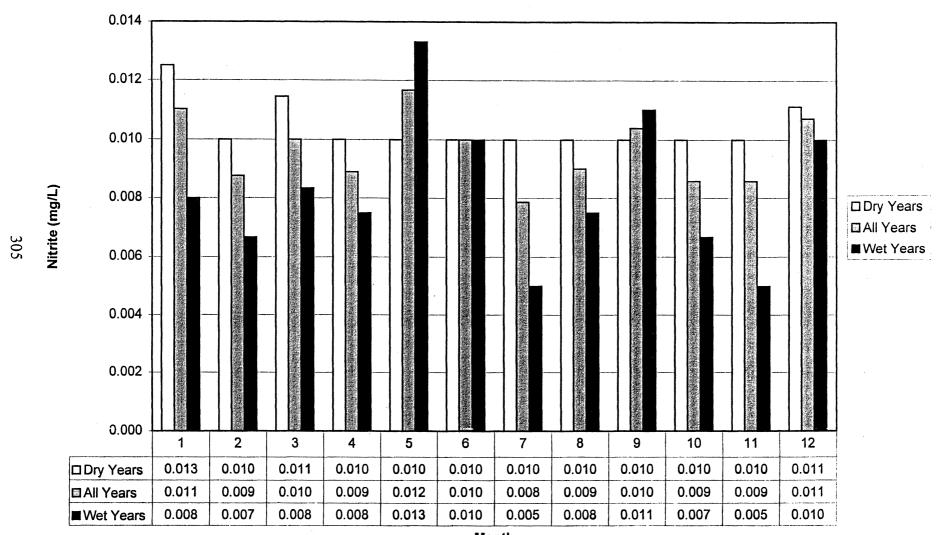
Ammonia in Sacramento R @ Freeport

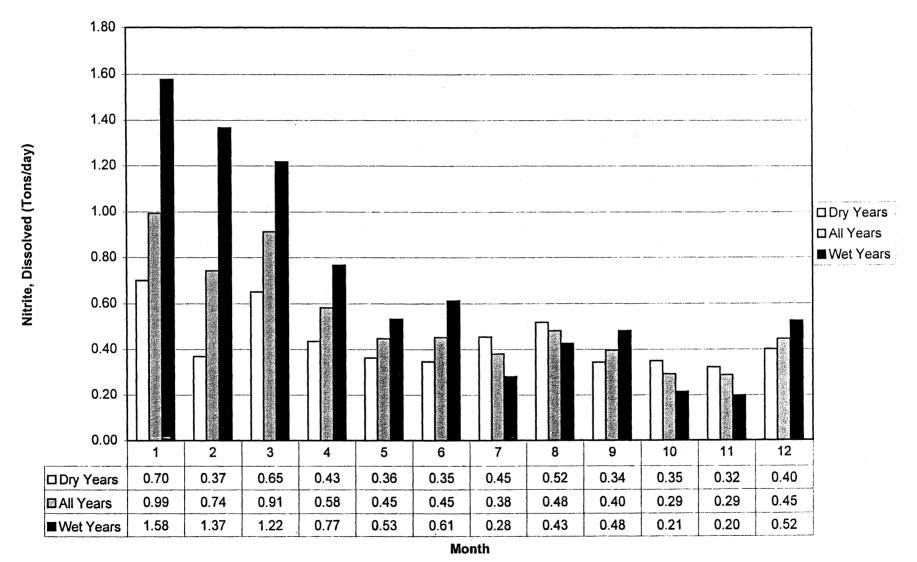


Ammonia in Sacramento R @ Freeport

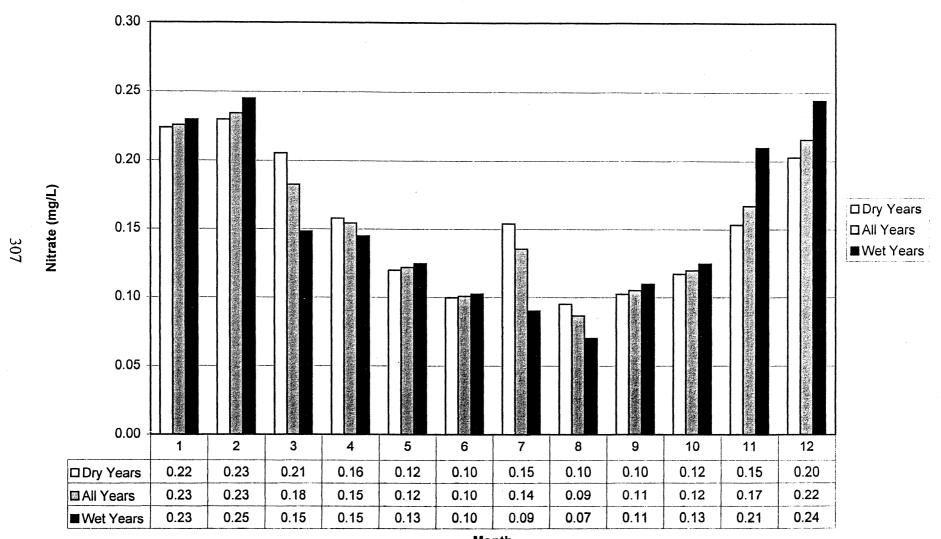


Nitrite in Sacramento R @ Freeport

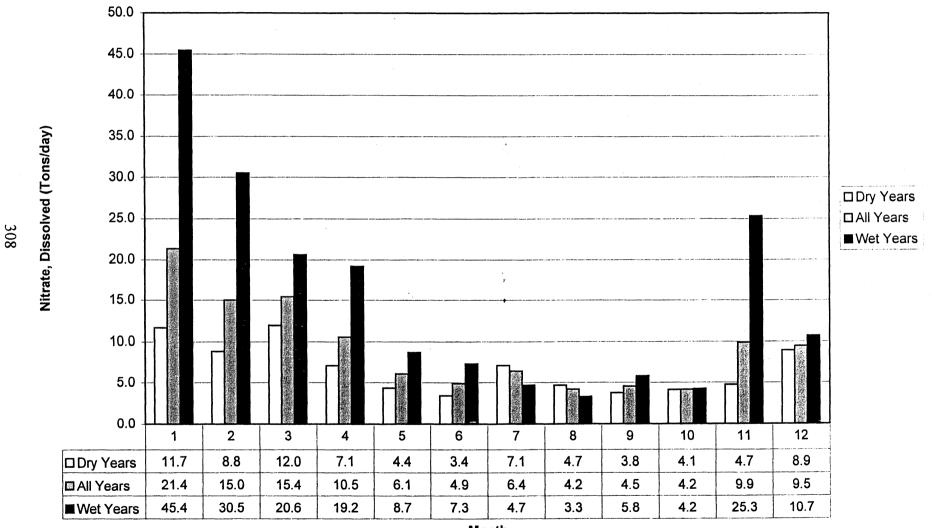




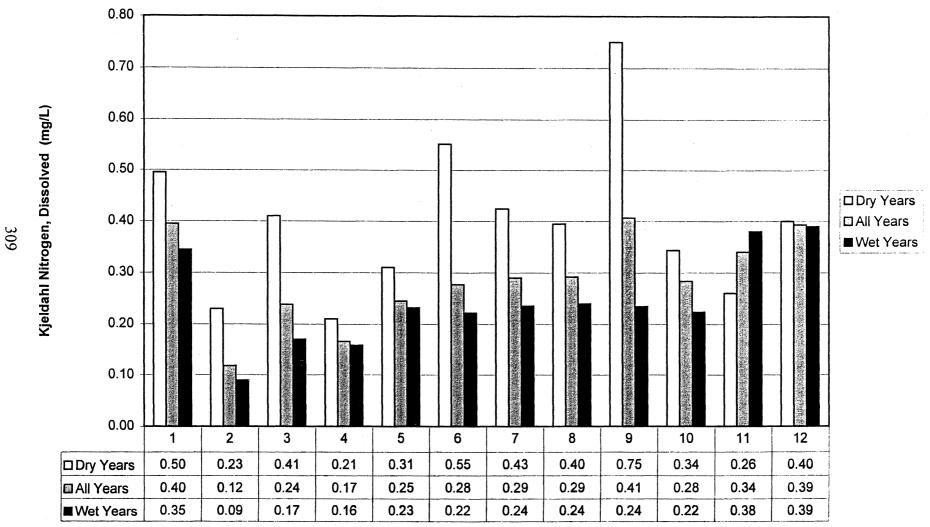
Nitrate in Sacramento R @ Freeport



Nitrate in Sacramento R @ Freeport



Kjeldahl N in Sacramento R @ Freeport



concentrations appear to increase only modestly during the periods during dry months of dry years when Kjeldahl nitrogen concentrations are high. This is an indication that much of the nitrogen may be in organic form, and could be due to increased primary productivity resulting from warmer temperatures and/or increased light penetration. Figure 8-15 shows that January of wet years is an important period for production of Kjeldahl nitrogen loads.

Historic total phosphorus is summarized in Figure 8-16. Over the relatively long record available, there is a preliminary appearance of reduced concentrations and loads after about the mid-1980's. If this change is real, it may be due to relocation of waste water treatment discharges from the American River to the Regional facility downstream, improved non-point pollution control measures, or other factors.

Figure 8-17 shows that August of dry years is associated with higher total phosphorus concentrations, and that the wet months are generally also associated with higher concentrations. Loads are distinctly higher in wet months of wet years, as is shown on Figure 8-18. Frequency distributions indicate the most often observed concentrations are in the 0.1 to 3 mg/L range, and loads are most frequently in the 5 to 15 Tons/day range. (Please refer to Figure 8-19 and Figure 8-20.)

Figure 8-21 shows average ortho-phosphate concentrations under different hydrologies. Wet months of dry years in particular, and dry years generally, are associated with higher concentrations. The pattern for loads, depicted in Figure 8-22 is for wet months of wet years to predominate.

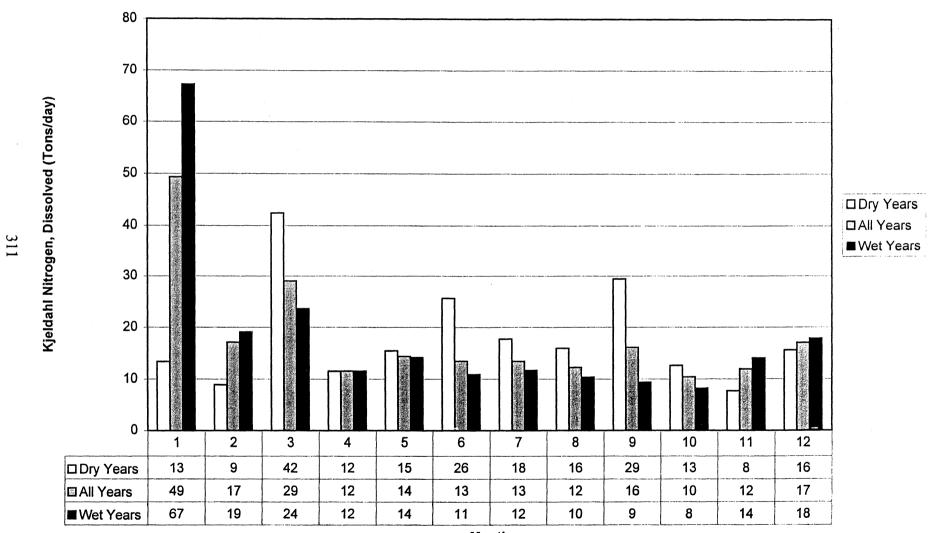
San Joaquin River near Vernalis

Figure 8-23 is a summary of historical total nitrogen concentrations measured in waters of the San Joaquin River near Vernalis. A maximum was experienced in March 1974 for reasons that are not evident. Flow at this time was about 5500 cfs, which is not unusual. Minima occurred during the period July through September 1977 during the historic drought when flows in the San Joaquin River were below 100 cfs. Another minimum occurred in November 1990 when flow was low (just over 1100 cfs), but not as low as it became later that season when total nitrogen concentrations did not reach minima.

Figure 8-24 indicates that total nitrogen concentrations are highest in March of wet years, and during that month generally. Load calculations, depicted in Figure 8-25, indicate wet months of wet years are most important, with March being a strong contributor. Frequency distributions shown in Figure 8-26 and Figure 8-27 indicate most total nitrogen concentrations are observed in the 1 to 5 mg/L range and that loads are most commonly found in the 10 to 40 Tons per day range.

Figure 8-28 shows average ammonia concentrations for different hydrologic year types. Wet months of wet years predominate, with wet months generally being associated with highest concentrations. Loadings follow a similar pattern with wet months of wet year

Kjeldahl N in Sacramento R @ Freeport

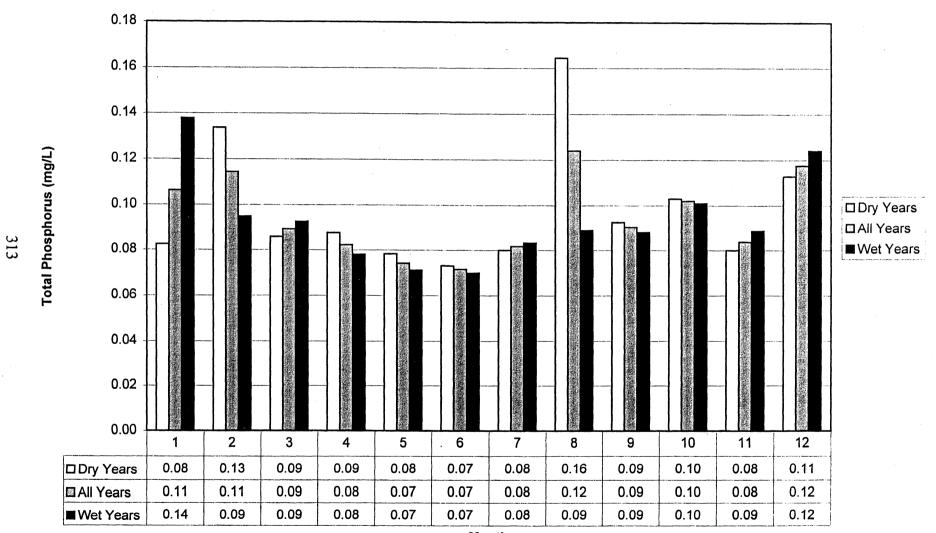


· Mass Load (Tons/day) 80/1/2 - Concentration (mg/L) TONE co_{N/2} 6/1/2 OSIA 68/1/2 TOPICS *O/I/S 60/1/2 G/1/2 18/1/2 00/1/2 SLIP 100.001 10.00 1.00 0.01 Total Phosphorus

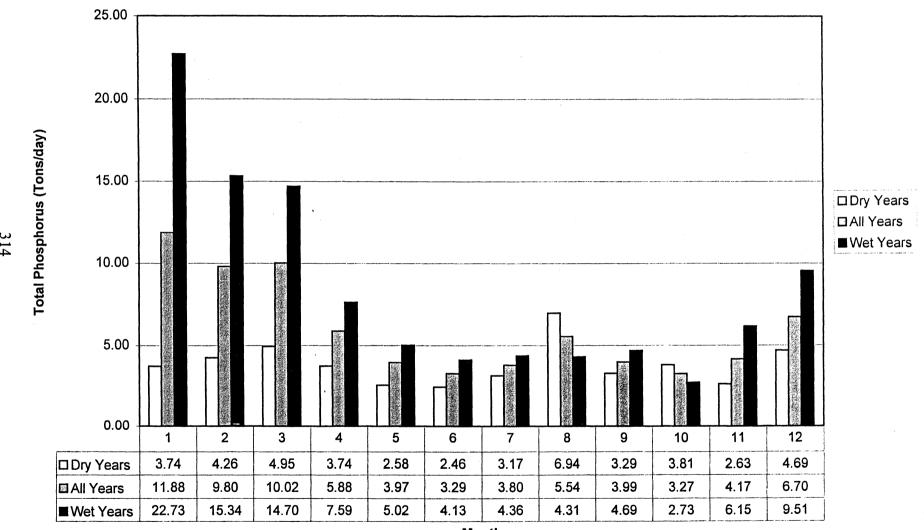
Total Phosphorus in Sacramento R @ Freeport

312

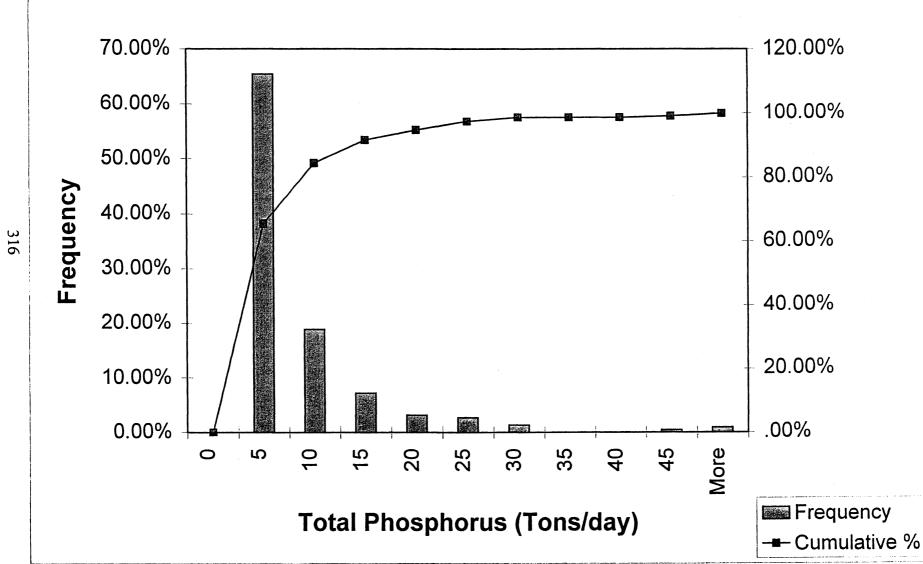
Total Phosphorus in Sacramento R @ Freeport



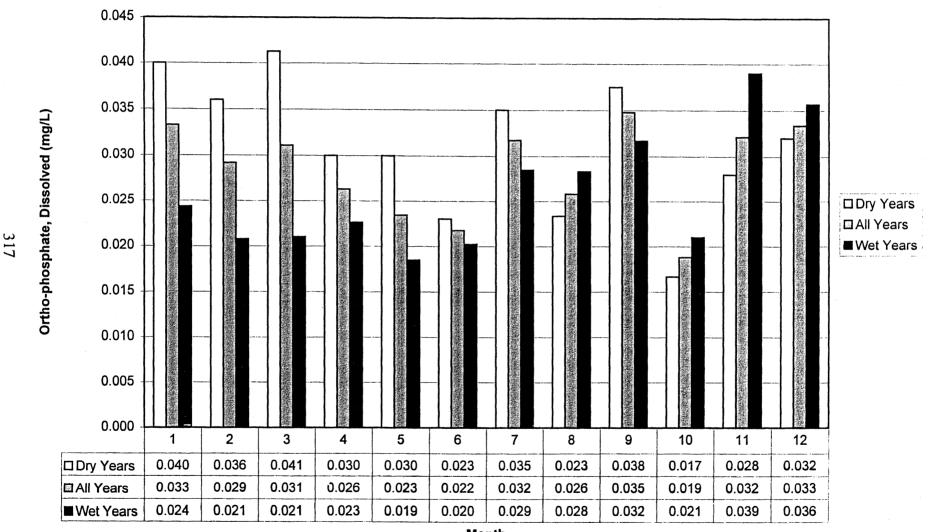
Total Phosphorus in Sacramento R @ Freeport



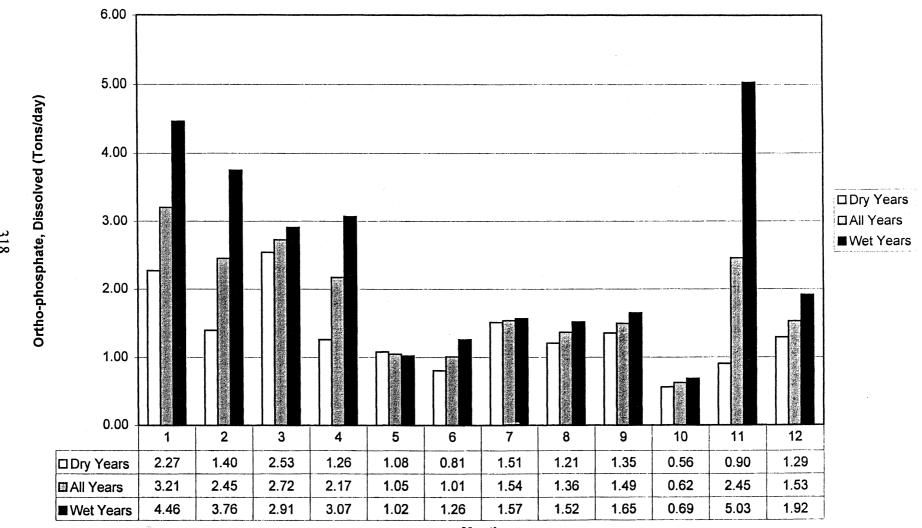
Total Phosphorus in Sacramento R. @ Freeport



Ortho-phosphate in Sacramento R @ Freeport



Ortho-Phosphate in Sacramento R @ Freeport

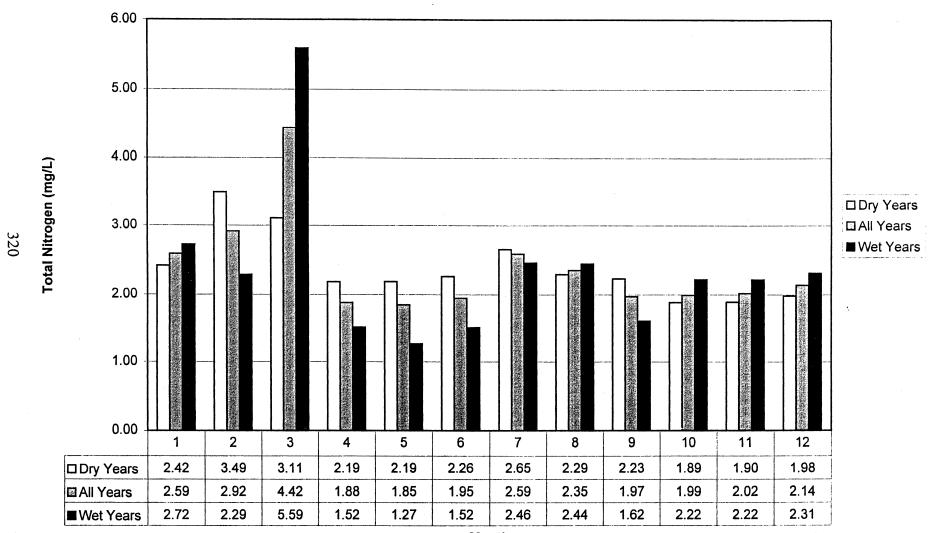


Mass Load (Tons/day) Concentration (mg/L) 10/2/2 Time 18/2/2 100.001 0.10 10.00 1.00 10000.00 1000.00 Total Nitrogen

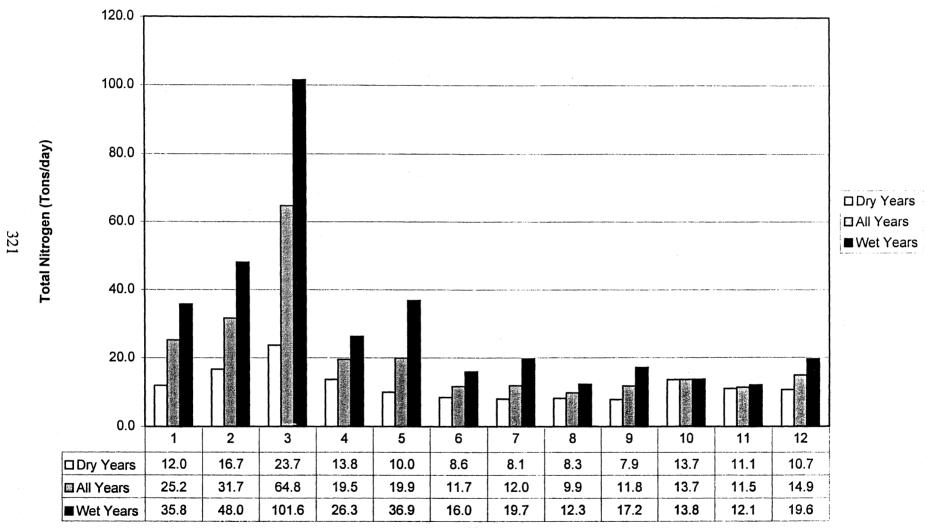
Total Nitrogen in S.J.R. nr. Vernalis

319

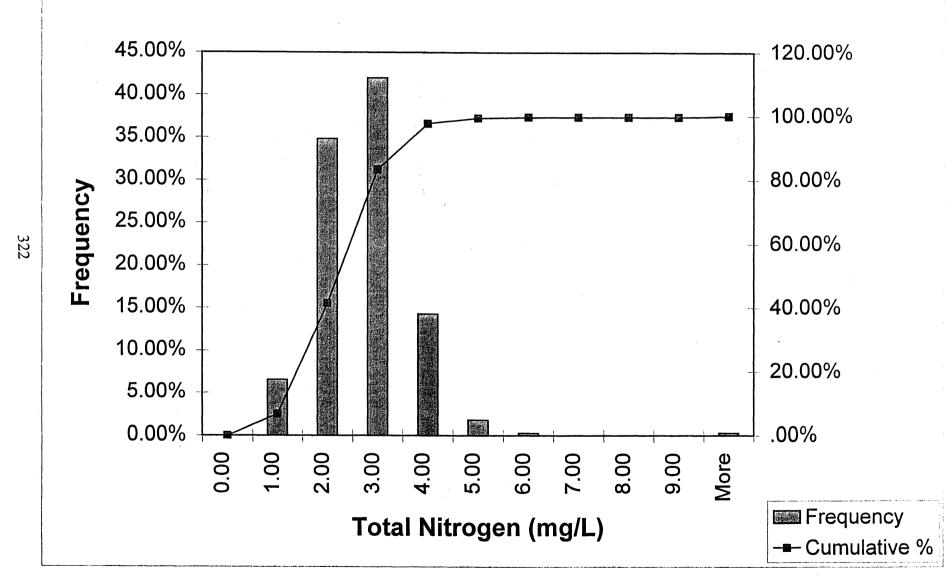
Total Nitrogen in S.J.R. nr. Vernalis



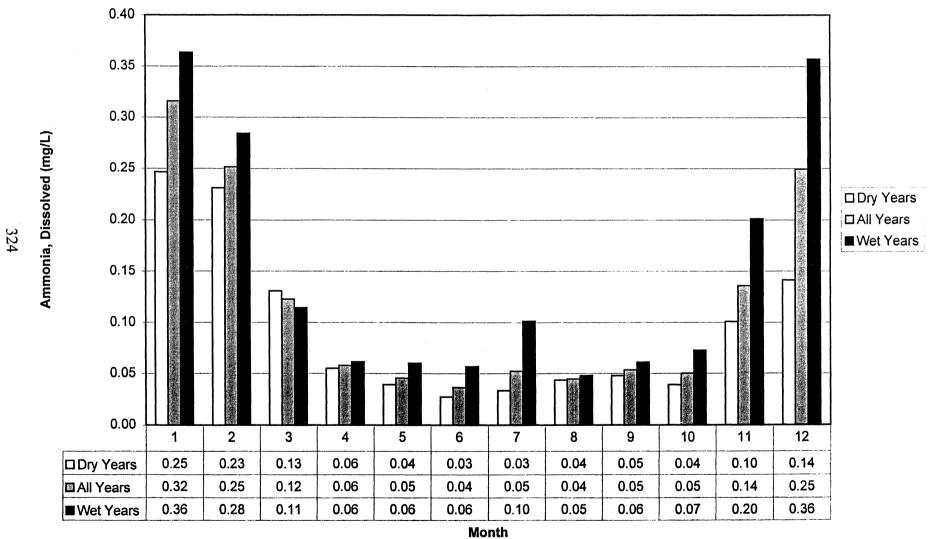
Total Nitrogen in S.J.R. nr. Vernalis



Total Nitrogen in S.J.R. nr. Vernalis



Ammonia in S.J.R. nr. Vernalis



being predominant, and wet months being generally associated with higher ammonia loads (Figure 8-29).

Nitrite is depicted in Figure 8-30. Wet months are associated with some increase in concentrations, and this effect tends to be more pronounced in wet years. Figure 8-31 shows that nitrite loads in the San Joaquin River during wet months of wet years are a predominant influence. Loads in the wetter months increase generally.

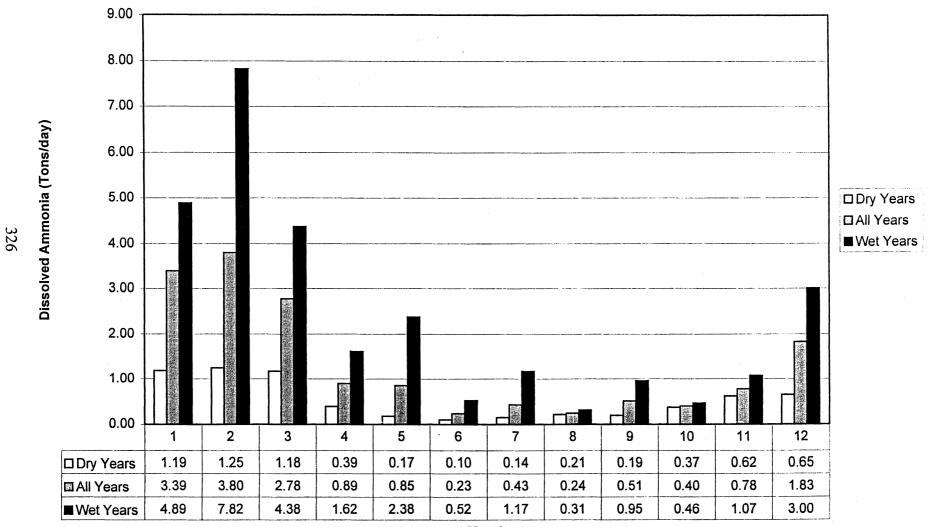
Nitrate concentrations are summarized in Figure 8-32. Wet months of dry years are associated with highest concentrations and spring months of wet years are associated with the lowest, probably related to reservoir releases. Loads are summarized in Figure 8-33, that indicates winter months of wet years are associated with highest loads, whereas summer months of dry years are associated with the lowest.

Kjeldahl nitrogen (organic nitrogen plus ammonia) concentrations, depicted in Figure 8-34, are highest in wet months of wet years. Loads, as reflected in Figure 8-35, are highest in the winter and spring months of wet years, probably reflecting beneficial effects of reservoir releases.

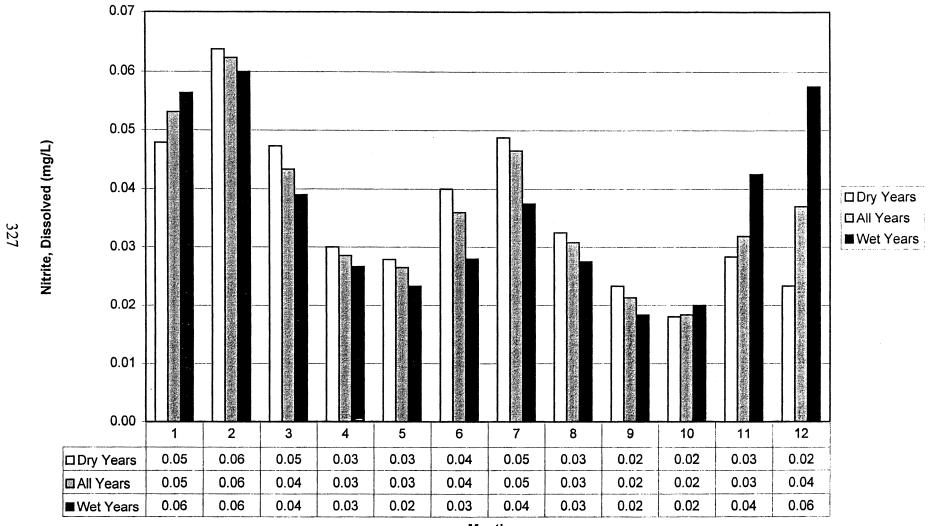
An historical summary of total phosphorus concentrations measured by the U.S. Geological Survey in the waters of the San Joaquin River near Vernalis is shown in Figure 8-36. No long term trends of change are readily apparent. Average monthly concentrations were plotted for different hydrologic year types and presented in Figure 8-37. There appears to be a pattern of greater concentrations in the wetter months. Figure 8-38 demonstrates a pronounced pattern of greater loadings associated with wet months of wet years and for the wetter months generally. Frequency distributions displayed in Figure 8-39 and Figure 8-40, indicate the most frequently observed concentrations and loads are in the 0.1 to 6 mg/L and 1 to 4 Tons/day ranges.

Figure 8-41 summarizes ortho-phosphate concentrations, and shows wet months as being associated with higher concentrations, with wet months of wet years being highest. Wet months of wet years are associated with pronounced increases in loads, as shown in Figure 8-42.

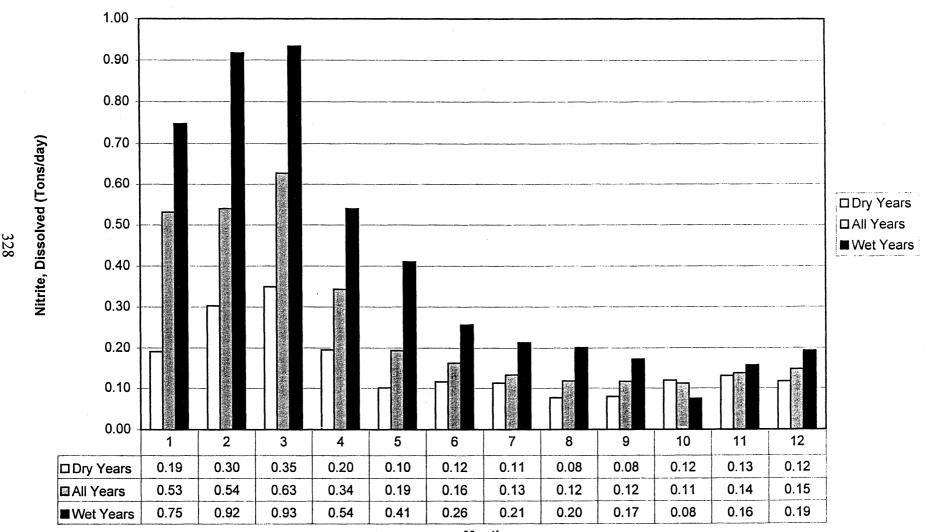
Dissolved Ammonia in S.J.R. nr. Vernalis



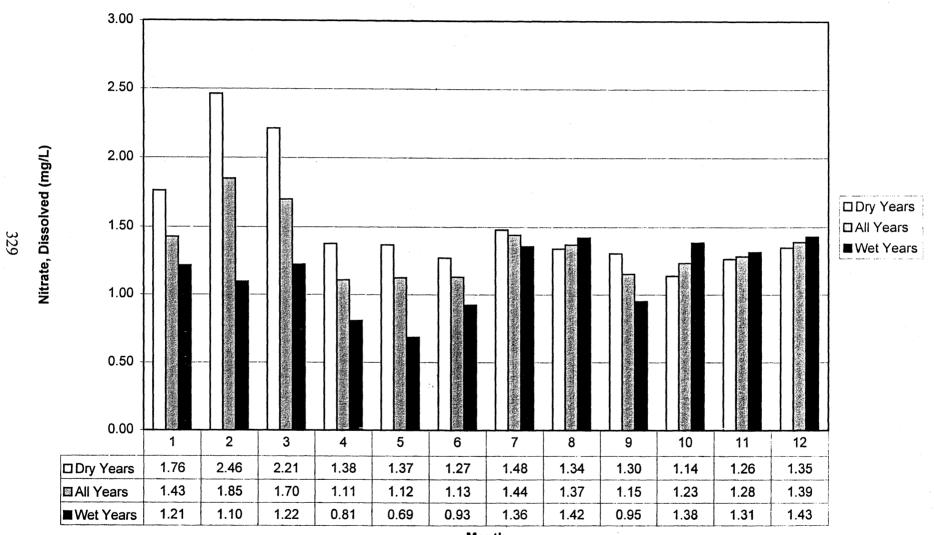
Nitrite in S.J.R. nr. Vernalis



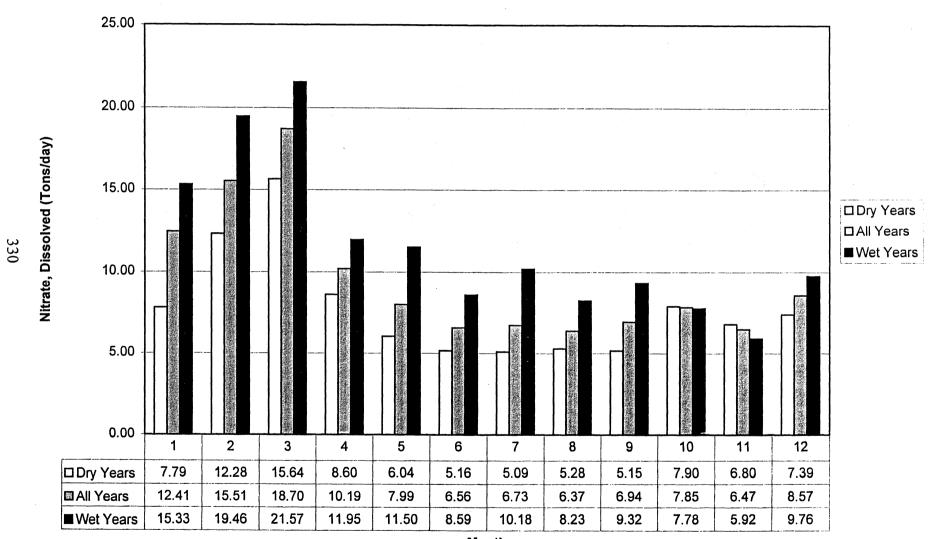
Nitrite in S.J.R. nr. Vernalis



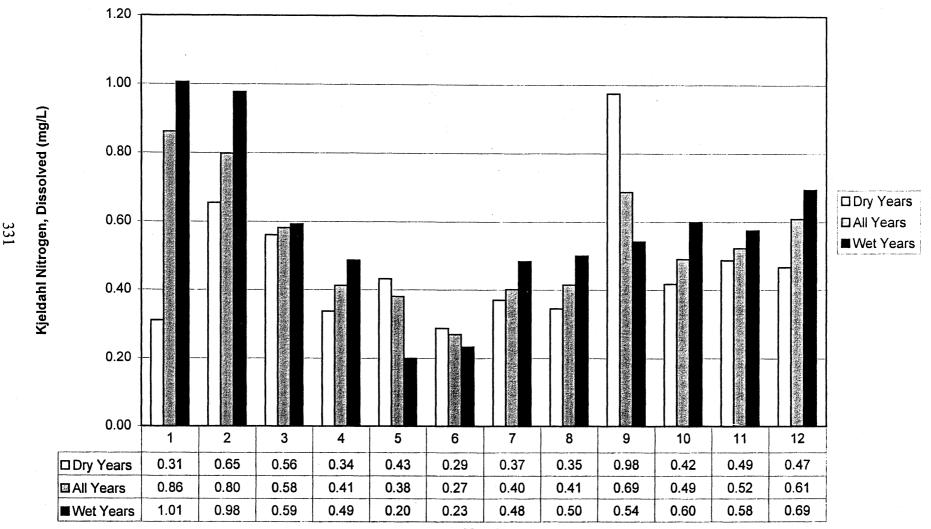
Nitrate in S.J.R. nr. Vernalis



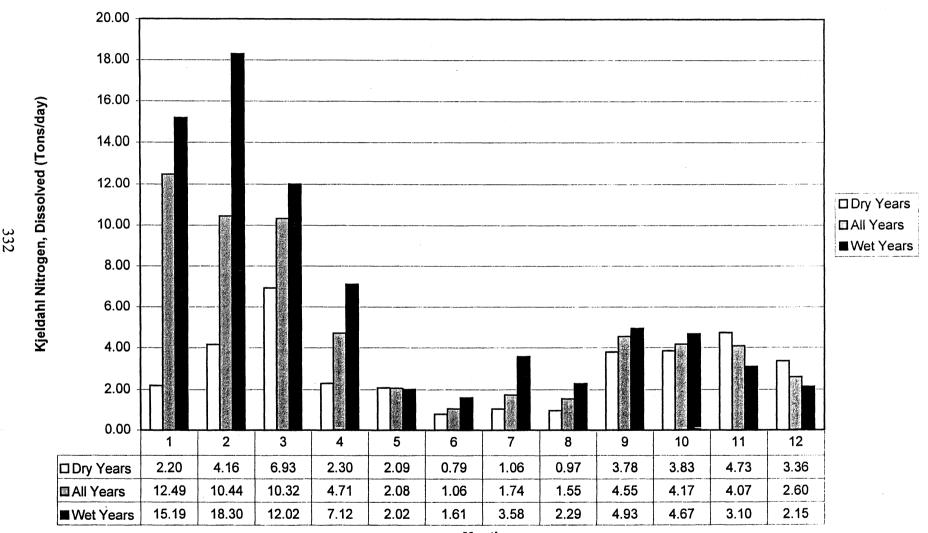
Nitrate in S.J.R. nr. Vernalis



Kjeldahl Nitrogen in S.J.R. nr. Vernalis



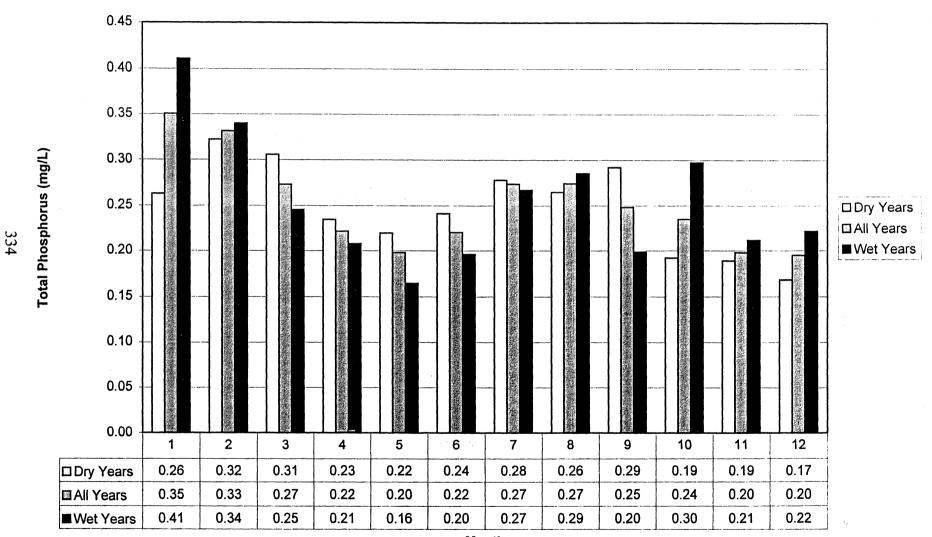
Kjeldahl Nitrogen in S.J.R. nr. Vernalis



Mass Load (Tons/day) - Concentration (mg/L) LIACI 0.01 100.00 10.00 1.00 Total Phosphorus

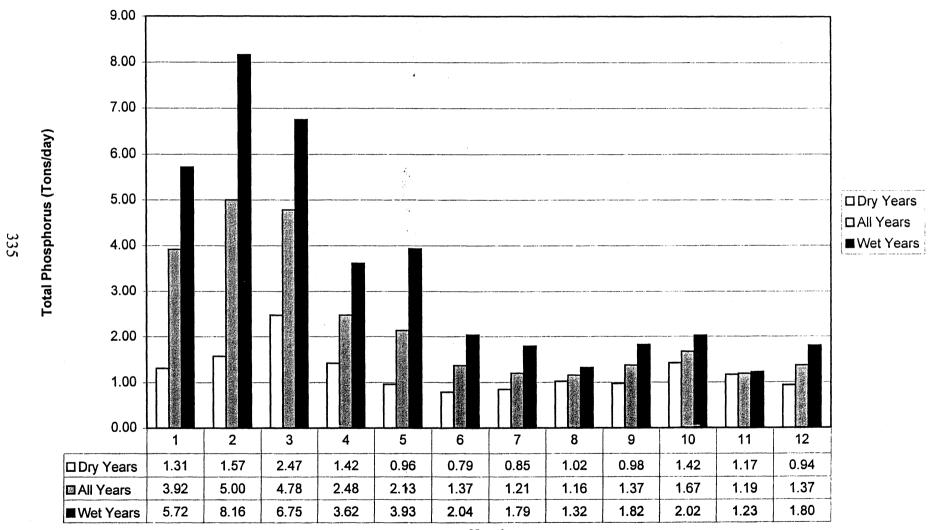
Total Phosphorus in S.J.R. nr. Vernalis

Total Phosphorus in S.J.R. nr. Vernalis



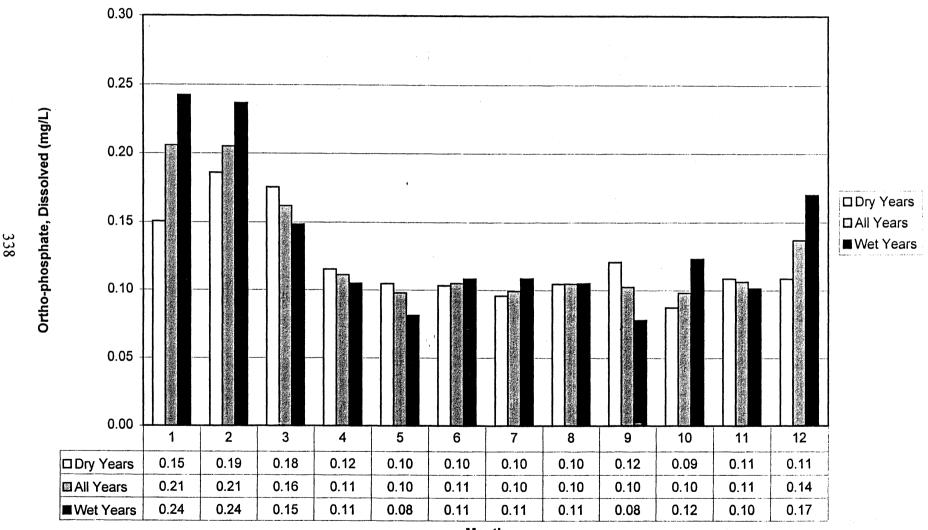
Month

Total Phosphorus in S.J.R. nr. Vernalis



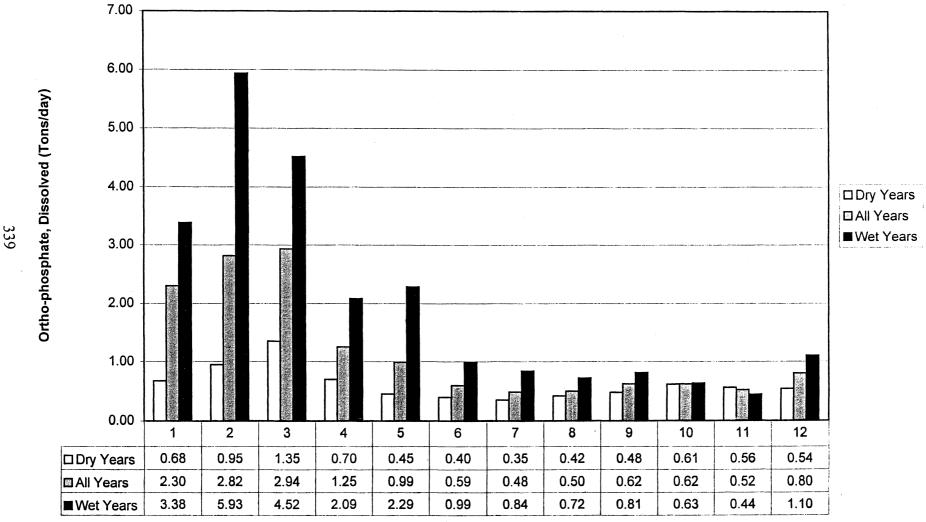
Month

Ortho-phosphate in S.J.R. nr. Vernalis



Month

Ortho-phosphate in S.J.R. nr. Vernalis



Month

The State Water Project

The State Water Project is a source of drinking water to about two-thirds of the population of California. Areas served by the State Water Project include the North Bay area through the North Bay Aqueduct, the South Bay area through the South Bay Aqueduct, coastal communities through the Coastal Branch of the California Aqueduct, and Southern California through the East Branch and West Branch of the California Aqueduct. Figure 1-2 depicts the areas served by the State Water Project.

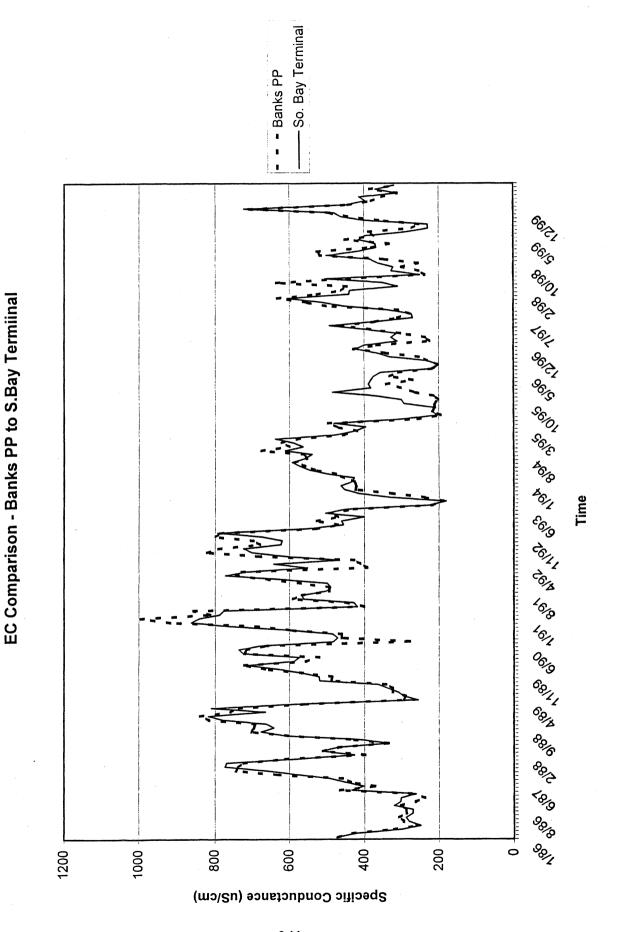
The North Bay Aqueduct is entirely pipeline and is not subject to significant water quality degradation after water is diverted into the aqueduct through North Bay Pumping Plant. Water quality at that location has been discussed in some detail elsewhere in this report.

Water is taken into the California Aqueduct of the State Water Project through the H.O. Banks Delta Pumping Plant, which diverts water from Old River in the South Delta, through Clifton Court Forebay. Some of the water entering the State Water Project is taken from Old River in the south Delta through the Tracy Pumping Plant of the federal Central Valley Project. Water from this locations flows south in the Delta Mendota Canal to O'Neill Forebay, which connects the state and federal projects. Intermixed water flows from O'Neill Forebay south to serve drinking water customers on the Coastal Branch, East Branch, and West Branch of the California Aqueduct. Santa Clara Water District also takes intermixed water through San Luis Reservoir as a federal customer, in addition to taking water from the South Bay Aqueduct of the SWP as a State Water Project contractor.

Water entering the California Aqueduct in the Delta is generally protected from further degradation in the South Bay Aqueduct, and in the reach of the California Aqueduct to O'Neill Forebay, with the possible exception of accidental spills and potential water quality impacts from activities in the area, such as livestock grazing. There are not constructed drains along these aqueduct reaches that permit non-project inflows to occur.

Specific conductance (EC) is useful for determining the presence of non-project inflows to the system, as such flows would typically have a different EC than water diverted from the Delta. Figure 9-1 summarizes specific conductance (EC) measurements made by continuous recorders at Banks Pumping Plant and at the terminus to the South Bay Aqueduct. These data indicate that EC at both locations has tracked closely since 1986 and indicates minimal change in mineral quality as the water is transported from the Delta to the terminus of the South Bay Aqueduct. This analysis is not, however, sensitive to the presence of pathogens that could, perhaps, enter the South Bay Aqueduct from adjacent agricultural operations while not causing significant EC changes.

Water pumped into the Delta Mendota Canal (DMC) is of poorer mineral quality than that taken through Clifton Court into the State Water Project. One reason for this difference is that the gates of Clifton Court are operated on a tidal basis. During higher parts of the tidal cycle when the gates are open, the Sacramento River has a greater influence on the mineral quality than is the case at other tidal stages; so, the SWP gets a



generally better mineral quality. Another reason for the difference is that, especially during low flow conditions, Tracy Pumping Plant tends to divert a large proportion of the flow of the San Joaquin River, and this source is saltier than water originating in the Sacramento River.

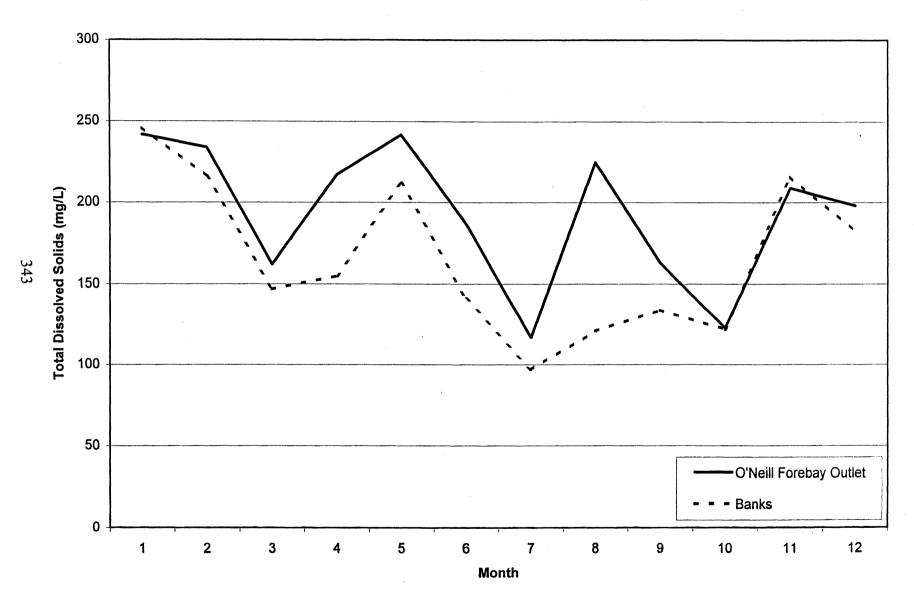
The overall average TDS measured at Banks Pumping Plant (through DWR's Municipal Water Quality Investigations Program) is 254 mg/L, while the average at the intake to the DMC is 280 mg/L, a 9 percent difference overall. In addition, unlike the reach of the California Aqueduct between Banks and O'Neill Forebay, the reach of the DMC between the Tracy Pumping Plant and O'Neill Forebay receives local drainage along the aqueduct. The result is that, once intermingled in O'Neill Forebay and San Luis Reservoir, the quality of water flowing south from O'Neill Forebay is not as good from a mineral perspective. Figure 9-2 compares average monthly TDS measurements based on analysis of discrete samples from these locations collected by the Division of Operations and Maintenance of DWR. Water flowing in the California Aqueduct south of O'Neill Forebay was measured to be 14 percent higher, overall, in TDS than water pumped into the system through Banks and, as it clear from the figure, higher in almost all months. These data suggest that local drainage into the DMC may account for about a 5 percent TDS increase over the 9% increase that occurs at the point of diversion in the Delta, in drinking water supplies taken through the State Water Project south of O'Neill Forebay.

The reach of the California Aqueduct between O'Neill Forebay and Kettleman City is jointly owned by the State Water Project and Central Valley Project, was constructed by the federal partner and is operated by the state. Unlike other reaches of the California Aqueduct, this reach of aqueduct, known as the San Luis Reach, has drainage inlets that allow storm drainage from the west side (upslope side) of the aqueduct to enter the system during wet weather. Limited data collected from drainage flowing into the aqueduct indicate their quality is variable but, in general, these drainages are small in volume. Exceptions are Little Panoche Creek, Cantua Creek, Salt Creek, and Arroyo Pasajero, west side streams that are intersected by the aqueduct, and into which flood waters flow, sometimes in significant quantities. Additionally, during drought emergencies, the State Water Project has allowed ground water from adjacent properties to be conveyed for the purpose of reducing hardship to farmers in the area. As the local ground water is generally of poorer mineral quality, the effect has been to somewhat reduce the quality of water in the California Aqueduct during these times.

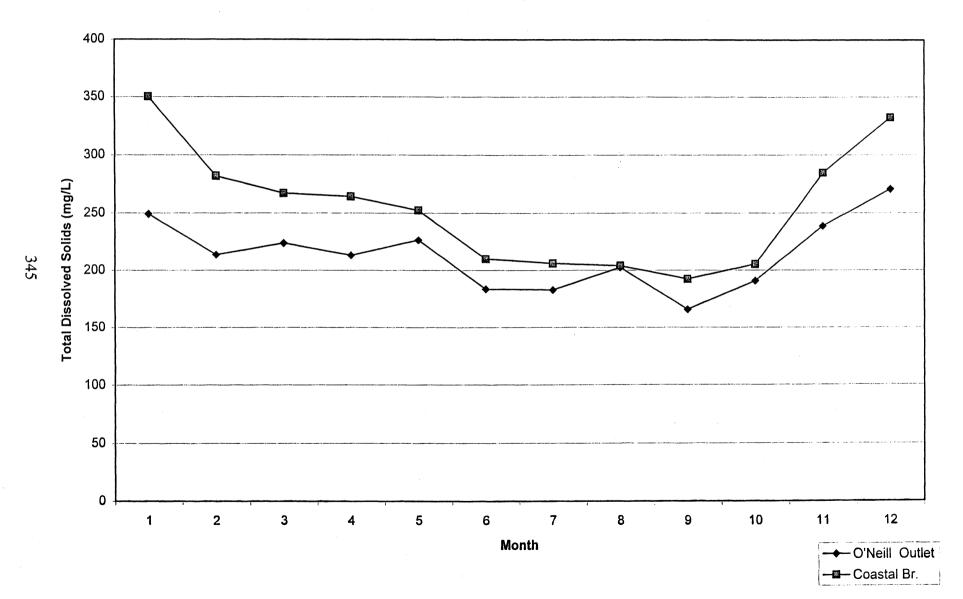
Figure 9-3 depicts monthly averages of TDS concentrations measured in samples from the outlet to O'Neill Forebay (Check 13, California Aqueduct), and Kettleman City (Check 21, California Aqueduct). As can be seen, the latter location is often associated with higher TDS concentrations, 7 percent greater overall.

A few miles south of Kettleman City, is the Coastal Branch connection of the California Aqueduct. Figure 9-4 depicts water quality changes between O'Neill Forebay Outlet and Coastal Branch Check 4. The Coastal Branch is open aqueduct from its connection with the main California Aqueduct to this location, after which water enters the pipeline that continues west to serve the communities of San Luis Obispo and Santa Barbara. In the

TDS Comparison - Banks PP vs. O'Neill Forebay Outlet



TDS Comparison - O'Neill Forebay Outlet to Coastal Branch



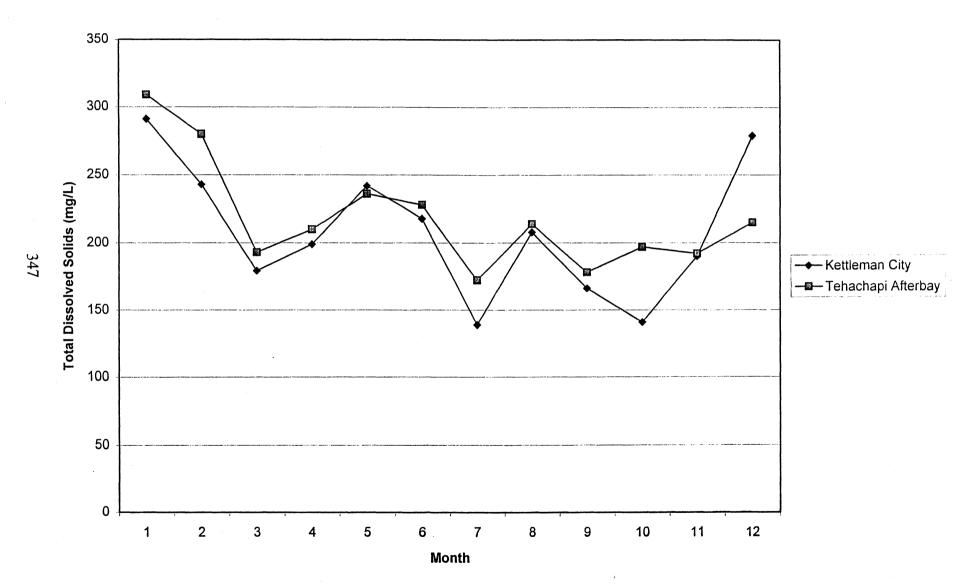
pipeline the water is protected from further mineralization. Overall there is a 16 percent increase in TDS as the water moved from O'Neill Forebay to Check 4 during the period 1995 to 2000 where data were available for analysis.

The reach of the California Aqueduct from Kettleman City to the bifurcation of the East and West Branches of the California Aqueduct (Tehachapi Afterbay) is not subject to many water quality influences other than the intertie of the California Aqueduct to the Kern River that exists in the Bakersfield area, and ground water seepage from the tunnels conveying the water through the Tehachapi Mountains for delivery to Southern California. Inflows of Kern River water occur only during flood periods and, when such flows flow into the aqueduct, the mineral quality of the flows is quite good, although large amounts of sediment can be carried into the aqueduct through this connection. Figure 9-5 depicts average monthly TDS concentrations at the two locations. TDS concentrations are about 5 percent higher, overall, at Tehachapi Afterbay, compared to Kettleman City. The lower average TDS recorded at Tehachapi Afterbay in December may reflect the influence of the Kern River during flood periods.

At Tehachapi Afterbay, the California Aqueduct branches. The West Branch flows through Pyramic Lake to Castaic Lake, from which drinking water diversions occur. The East Branch of the California Aqueduct goes across the high desert, serving the Palmdale area, to Silverwood Lake, from whence it flows through the mountains to the Devil Canyon Afterbay, then via pipeline to Lake Perris, the terminous of the East Branch, located in Perris Valley. Drinking water diversions occur at Devil Canyon and Lake Perris. Figure 9-6 compares monthly average TDS concentrations between Tehachapi Afterbay and Devil Canyon Afterbay on the East Branch. There is a 2 percent overall increase in TDS by the time the water reaches Devil Canyon. Some of this increase will be due to evaporation and salt concentration in Silverwood Lake and the aqueduct, and some may come from local seepage into the aqueduct and occasional storm drainage that may enter the aqueduct from a few East Branch locations.

Figure 9-7 presents a comparison of monthly average specific conductance, or electrical conductivity (EC) measured at Tehachapi Afterbay and Castaic Lake at the Metropolitan Water District of Southern California drinking water supply intake. EC data for both locations, available for the period since 1995, indicate significantly higher salt concentrations in Castaic Lake than at Tehachapi Afterbay, 30 percent higher overall. Castaic Lake has a 324,000 acre-foot capacity, and Pyramid Lake has a 171,000 acre-foot capacity as compared to Silverwood at 75,000 acre-feet. Therefore, the quality of water taken at Castaic reflects a six-fold greater buffering resulting from storage, as compared to water taken from Devil Canyon. (The volume of Lake Perris is not computed in this comparison because it is not often used for drinking water supply.) For this reason, water quality taken from Castaic is not likely to closely resemble the quality present at Tehachapi at any particular time. The higher salt content in Castaic Lake probably reflects residual effects from earlier hydrologic conditions, local drainage from the Pyramid and Castaic watersheds, and evaporation from the two reservoirs.

TDS Comparison - Kettleman City to Tehachapi Afterbay



The analyses of mineral constituents presented here are not intended to reflect pathogen levels that may occur in the State Water Project, particularly in drinking water supplies drawn from the reservoirs where body contact recreational activities occur. Also, human and wildlife activities in the watersheds of the four Southern California reservoirs may affect pathogen concentrations entering drinking water supplies in this area.

Comparison Among Key Monitoring Locations

As the two largest fresh water inflows to the Sacramento-San Joaquin Delta System, water quality measurements of the Sacramento River and San Joaquin River are very important for being able to understand the factors influencing the quality of drinking water supplies taken from the Delta. This is a discussion of current problems associated with monitoring the lower reaches of these streams and a preliminary comparison of data collected at different monitoring stations.

Sacramento River - Greenes Landing versus Hood

Hood is located on the Sacramento River about two miles upstream of Greenes Landing. These locations were chosen for monitoring because they tend to reflect all the upstream water quality influences on the water as it flows into the Delta. These locations are sufficiently upstream of the Bay that tidal influence does not normally cause flow reversals, so quality and flow measurements made at these places can be used to compute concentrations and mass loads of materials moving from the Sacramento River into the Delta. Water quality and flow monitoring has been conducted since the 1950's at least and, therefore, a very valuable historical record exists for this location.

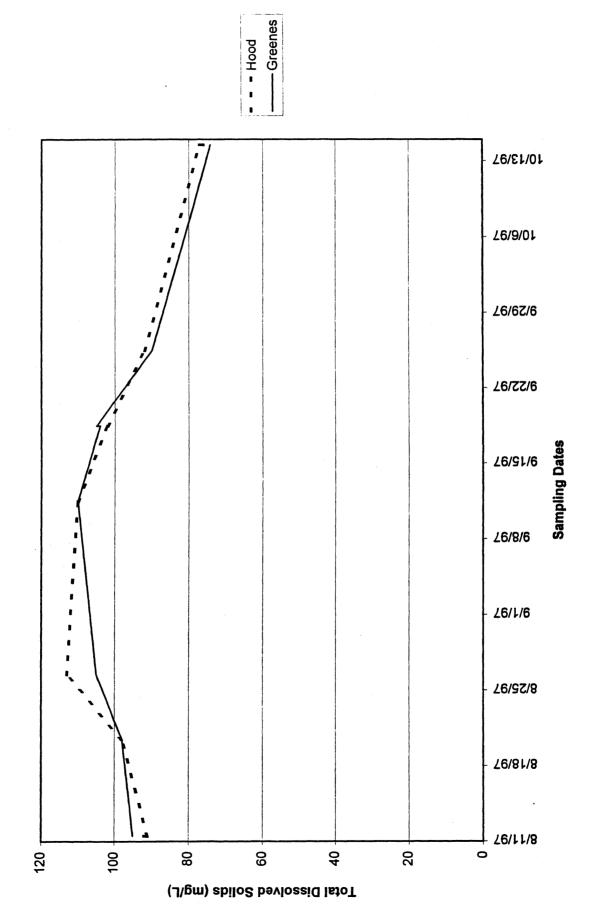
Monitoring has been accomplished from a constructed platform owned by the U.S. Bureau of Reclamation, and used by the Department of Water Resources and probably other agencies as well. Unfortunately, the structure is subject to strong forces when river flows are high, and it has weakened over the years to the point of being unsafe during high flow conditions. In view of the high cost and other complications that would be associated with rebuilding the monitoring station, a decision was recently made to build a new facility at Hood, a location that offers several logistical advantages. The station at Greenes Landing will be abandoned. Because the short reach of river between Hood and Greenes Landing is not believed to be subject to significant water quality influences, it has been supposed that data collected from the two locations are comparable. Data collected by the Department of Water Resources at both stations over the same time period are examined to provide a preliminary indication whether constituents of drinking water concern measured at these locations are, indeed, comparable.

Figure 10-1 is a plot showing total dissolved solids (TDS) concentrations measured at both stations on the same days. Figure 10-2 compares bromide, Figure 10-3 compares dissolved organic carbon (DOC), Figure 10-4 compares total organic carbon (TOC), Figure 10-5 compares nitrate, Figure 10-6 compares turbidity, and Figure 10-7 compares ultra violet absorbance readings for the two locations. While the data collected at the two stations appear to compare favorably in general, there is a question whether DOC, TOC and turbidity at the two stations are sufficiently comparable to enable data from both locations to be used together. Further detailed studies would be required to fully establish the comparability of the data.

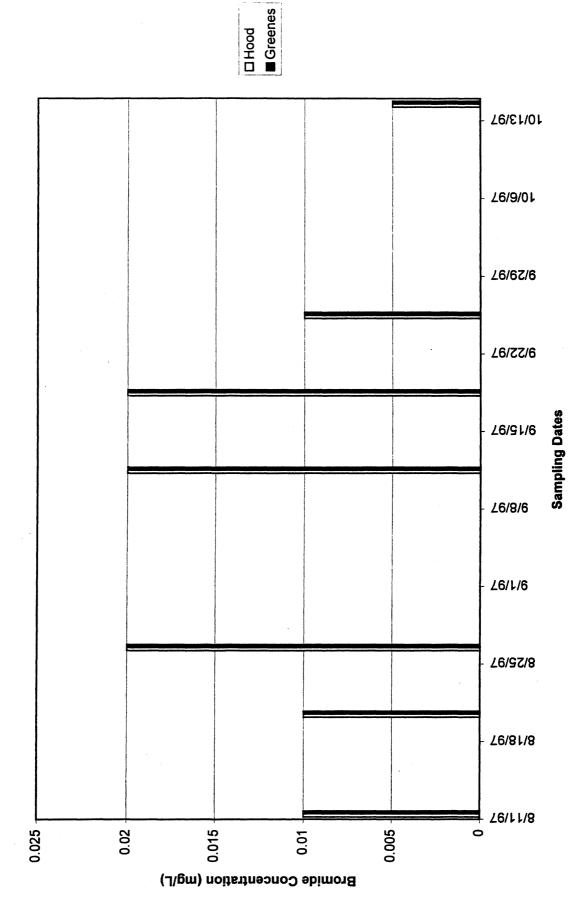
San Joaquin River - Vernalis versus Mossdale

As has been the case with the Sacramento River at Greenes Landing, the San Joaquin River near Vernalis has long been used by a number of agencies for monitoring the quality of water flowing into the Delta. And, as is the case with the Greenes Landing,

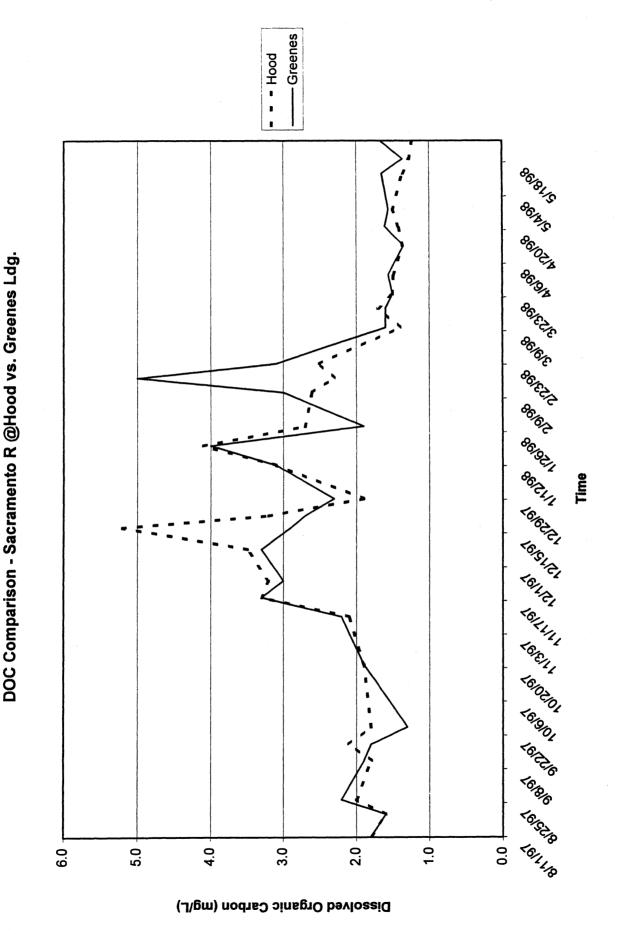
	Sales year, all real

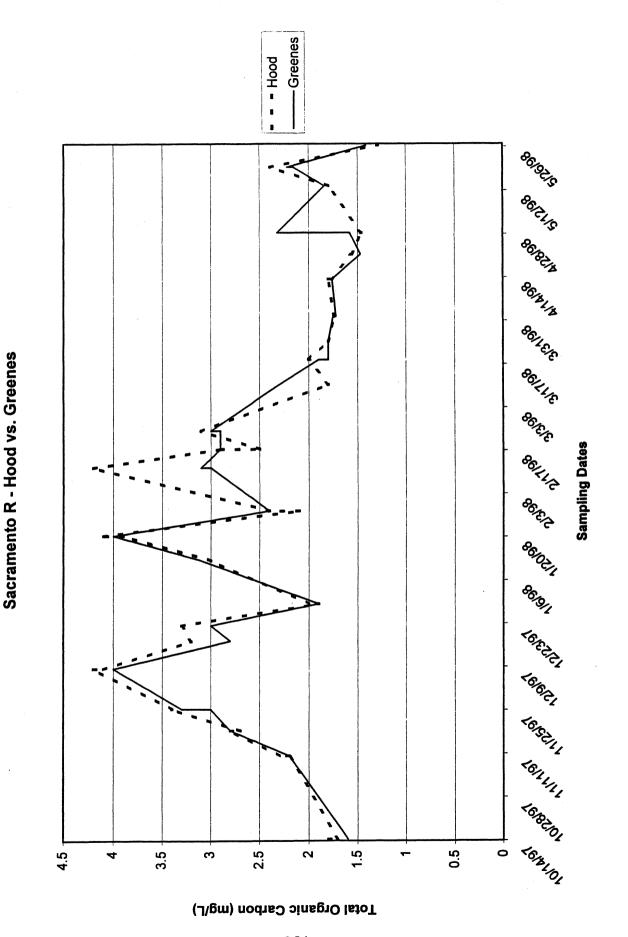


Sacramento R. - Hood vs. Greenes Ldg.

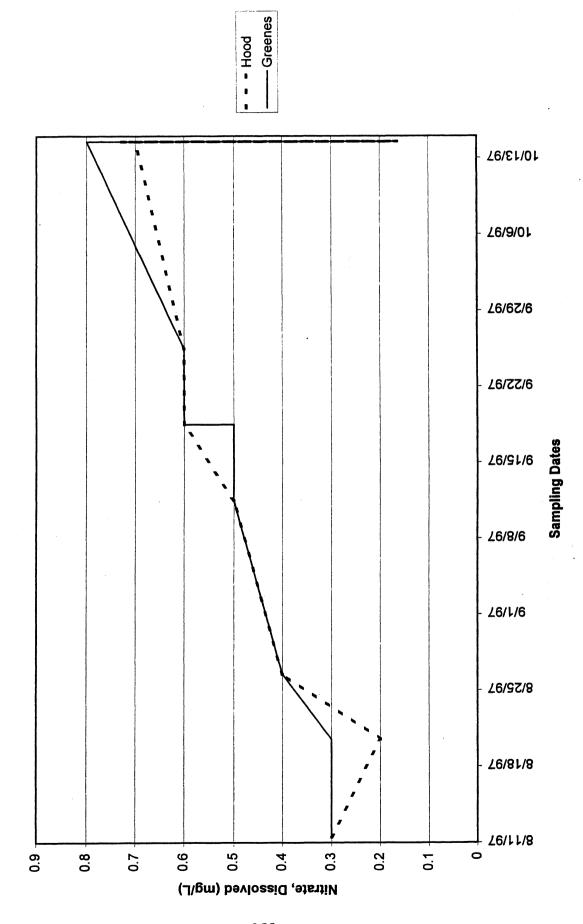


Sacramento R - Hood vs. Greenes Ldg.

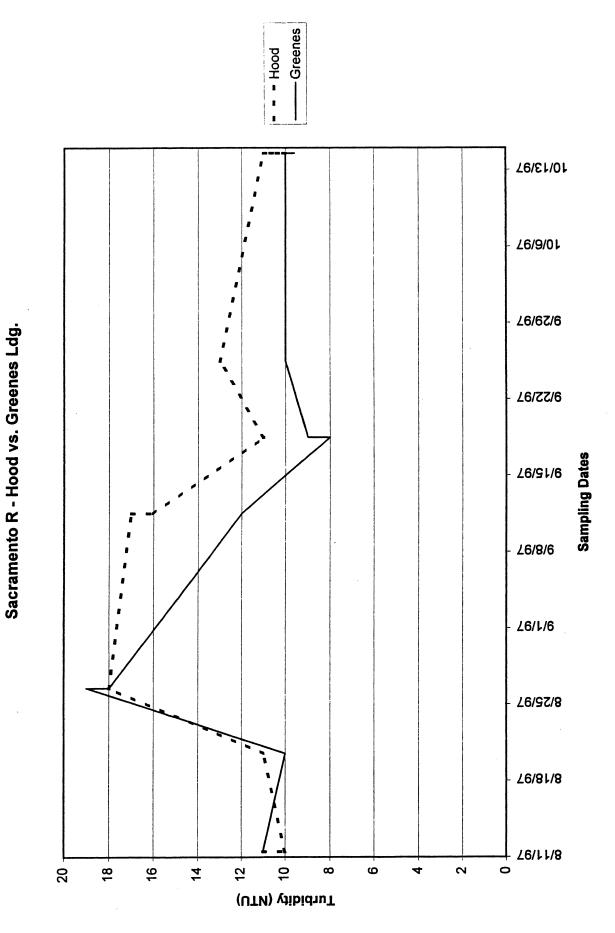


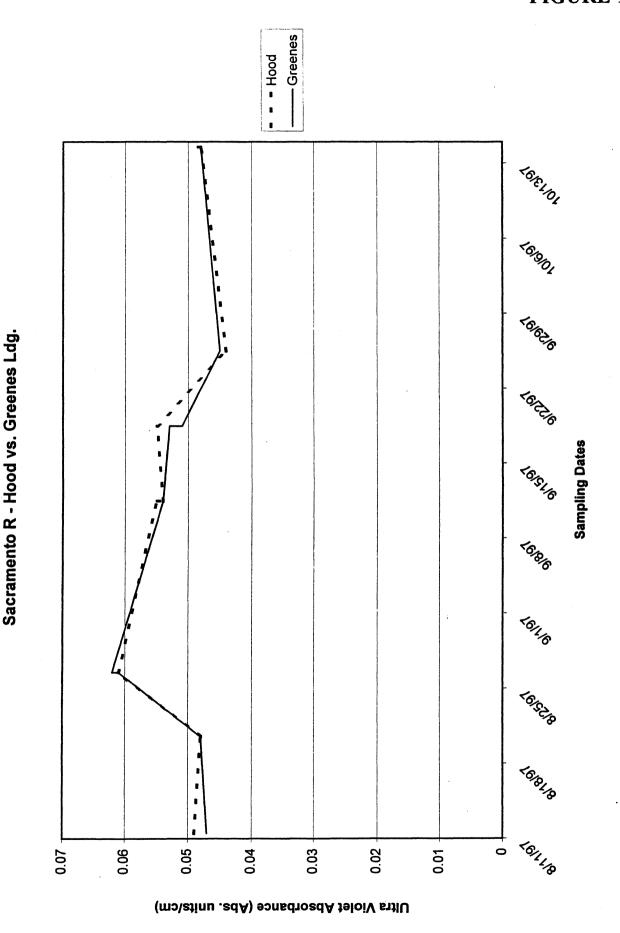


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Sacramento R. Hood vs. Greenes Ldg.



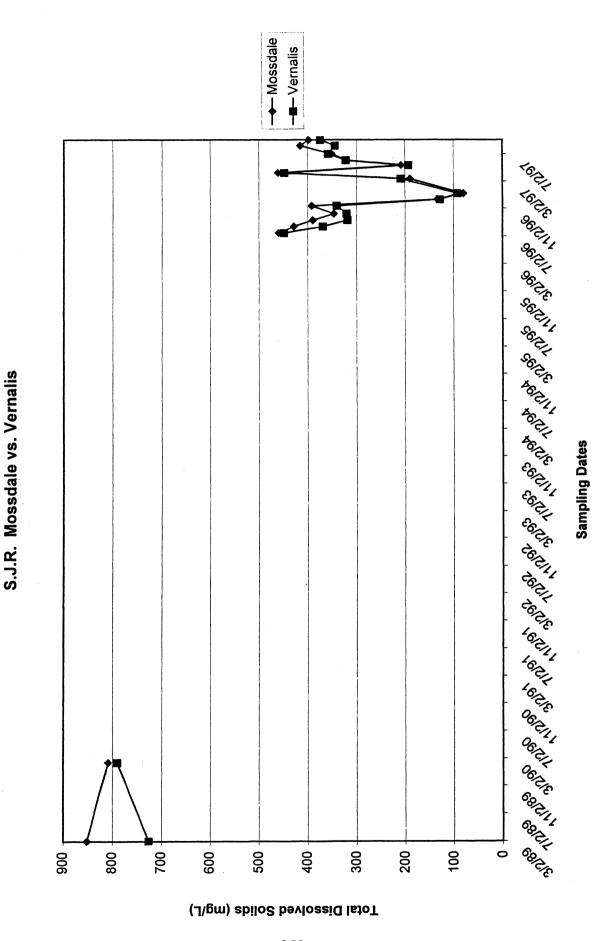


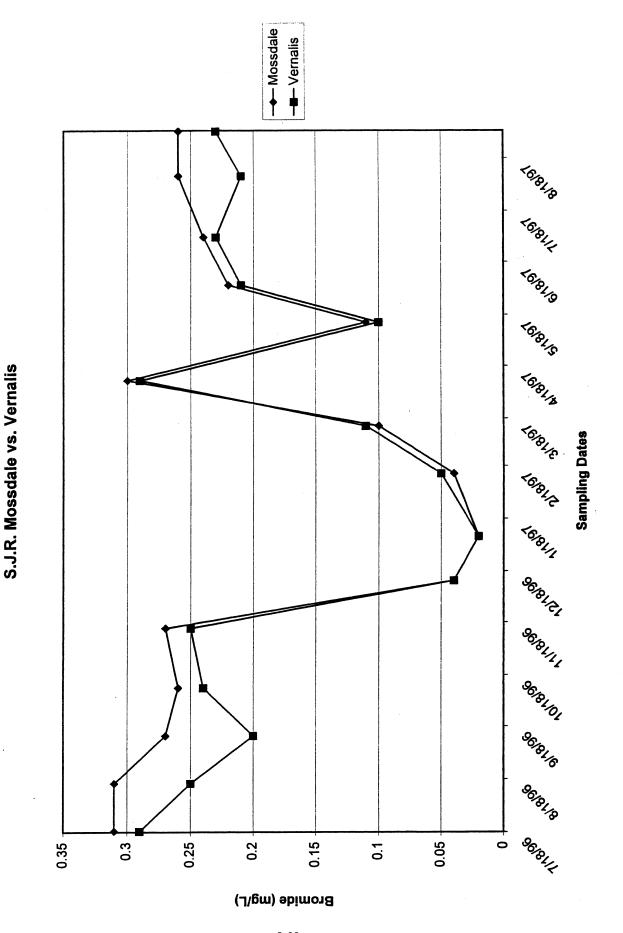
the location of the monitoring station is far enough downstream to well represent the influence of the San Joaquin River on the Delta, and far enough upstream to be sufficiently away from tidal influence to avoid flow reversals. There are, however, problems with this station. One problem is that it is only a little way downstream of the confluence of the Stanislaus River and may not, therefore, always be well mixed. Another problem is that, during low flow periods, it is not uncommon for water depth at this location to be so shallow as to strand automated sample probes, and to make collection of a representative discrete sample difficult. Also, sampling has been performed from a well-traveled bridge that is believed to present hazards to sampling personnel.

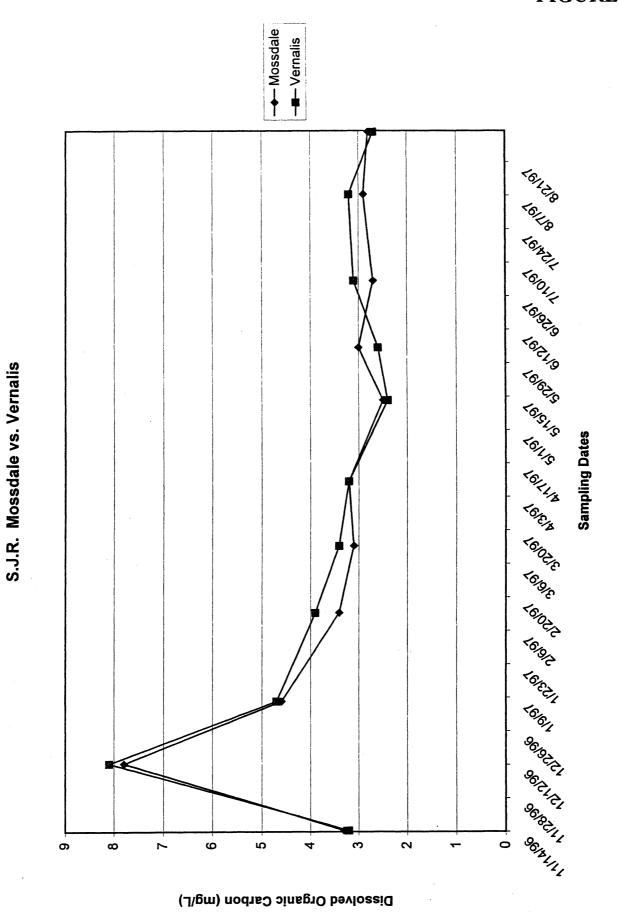
Due to these concerns, consideration is presently being given to constructing a housing for new automated monitoring equipment at a location downstream at Mossdale. Logistically, the Mossdale location is much to be preferred. A potentially serious drawback to the Mossdale location is that it is subject to significant tidal influence, which complicates the ability to measure flow and compute mass loadings. Another problem is that this location is downstream of the confluence of Paradise Cut and San Joaquin River. Under some conditions, pumping in the south Delta, particularly through the Tracy Pumping Plant, draws San Joaquin River water westward from the San Joaquin River through Paradise Cut to Old River, bypassing the San Joaquin River at Mossdale. This raises the question of whether flow and water quality monitoring at Mossdale are fully representative of the influence of the San Joaquin River on the Delta.

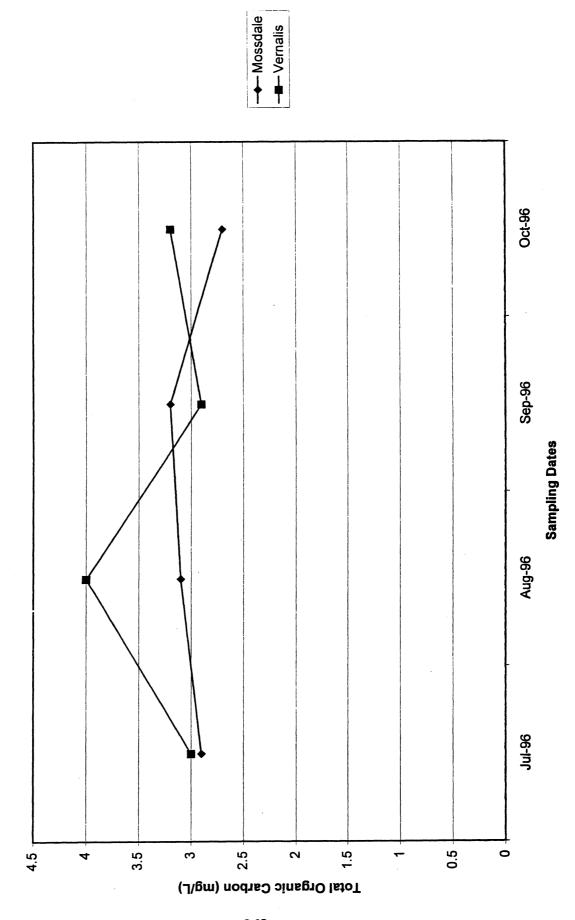
A preliminary analysis of available data on constituents of drinking water concern for the two locations collected by the Department of Water Resources on the same days follows. Figure 10-8 compares the very limited data on TDS. Figure 10-9 compares bromide, Figure 10-10 compares DOC, Figure 10-11 compares TOC, Figure 10-12 compares nitrate, Figure 10-13 compares turbidity, and Figure 10-14 compares ultra violet absorbance (UVA) readings taken at the two stations on the same sampling days. TDS and bromide concentrations measured at the two stations did not always compare favorably, though did on most sampling occasions. DOC appeared comparable, while TOC was not as comparable. Nitrate was generally comparable, as was UVA, but there appears to be some question as to the comparability of turbidity data at the two locations.

Because of the high value of the very long historical record at Vernalis, it is highly desirable to maintain collection of data that can be used together with historical data at Vernalis. Further studies would be required to fully establish the comparability of data collected at the Vernalis and Mossdale monitoring stations.

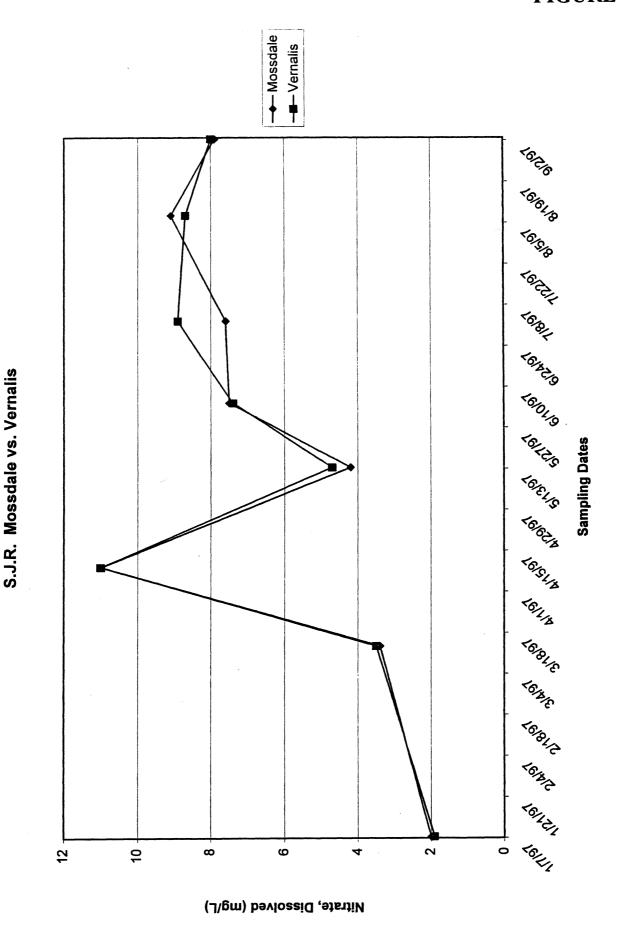


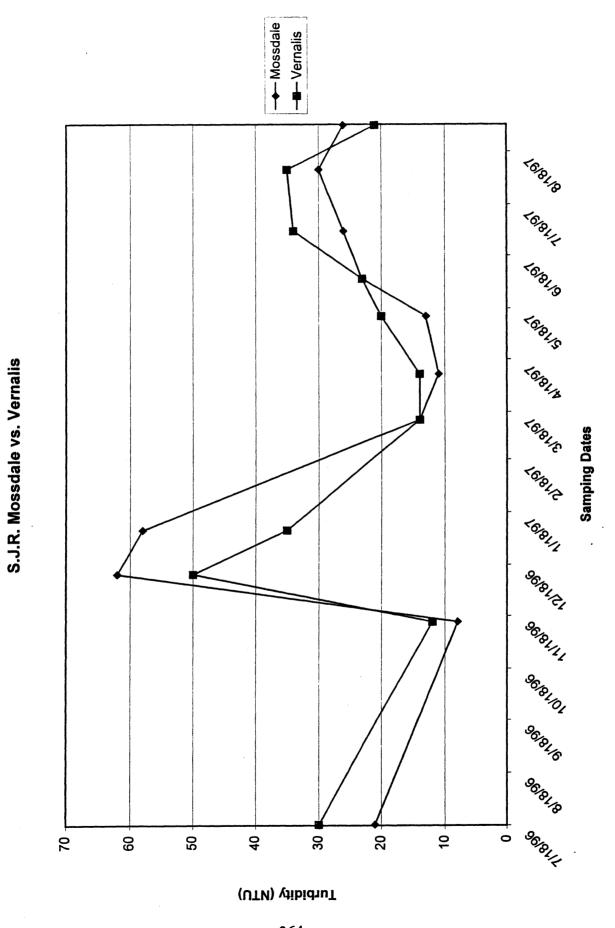




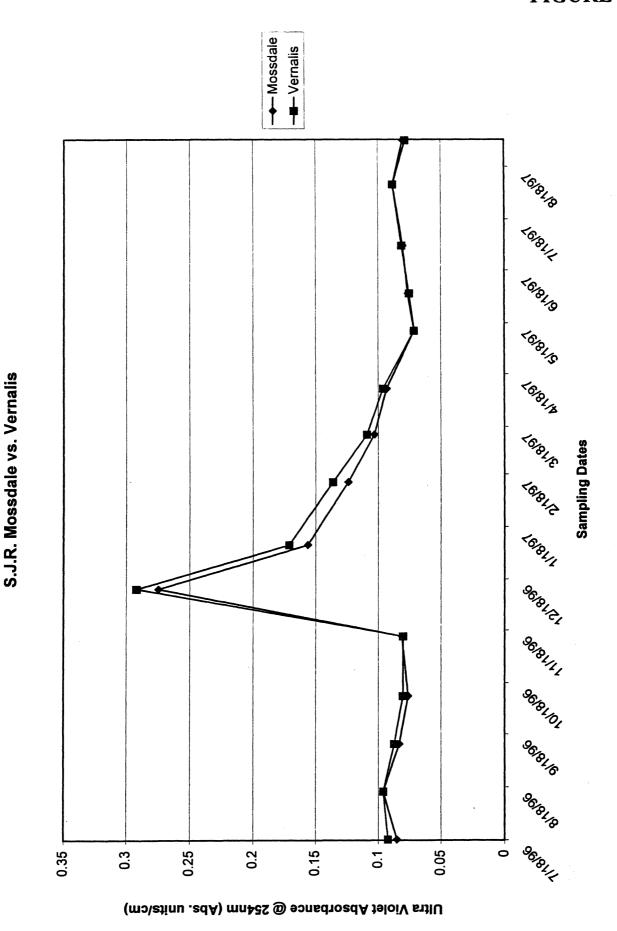


S.J.R. Mossdale vs. Vernalis





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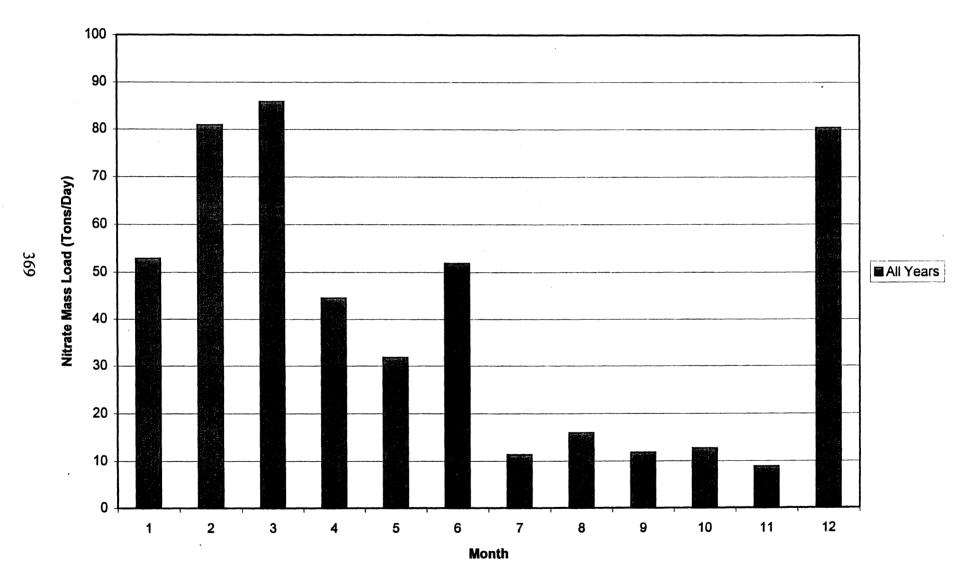


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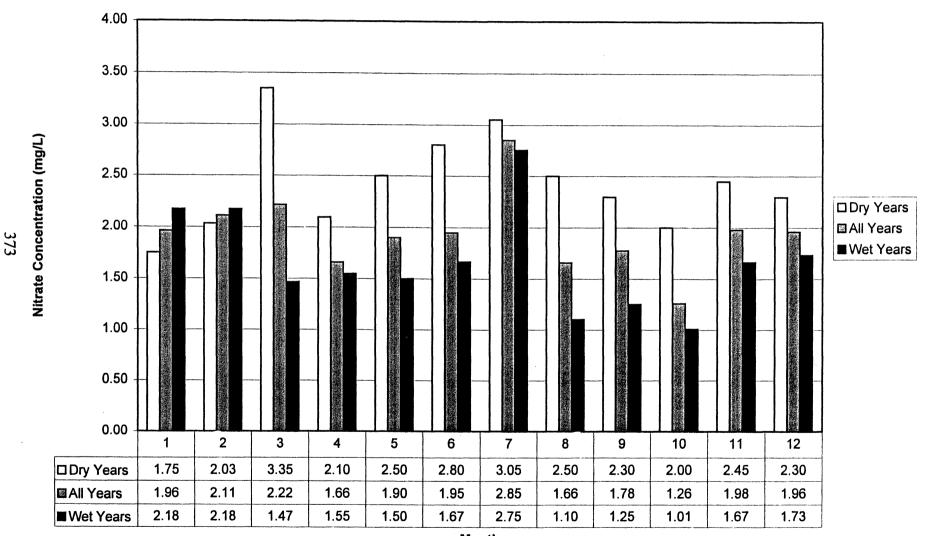
APPENDIX A

SUMMARY OF NITRATE DATA
COLLECTED BY THE DEPRTMENT OF WATER RESOURCES
MUNICIPAL WATER QUALITY INVESTIGATIONS PROGRAM

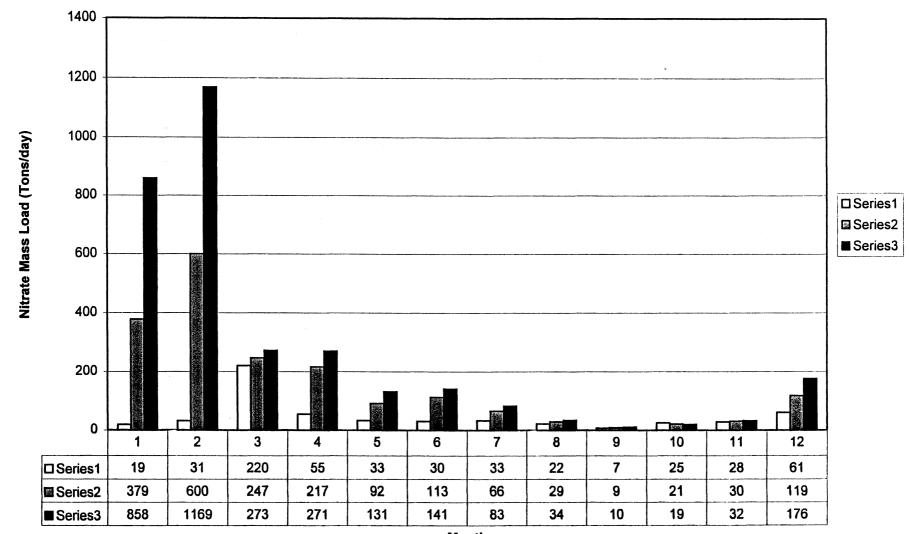
Nitrate in Sacramento R @ W. Sac. Intake



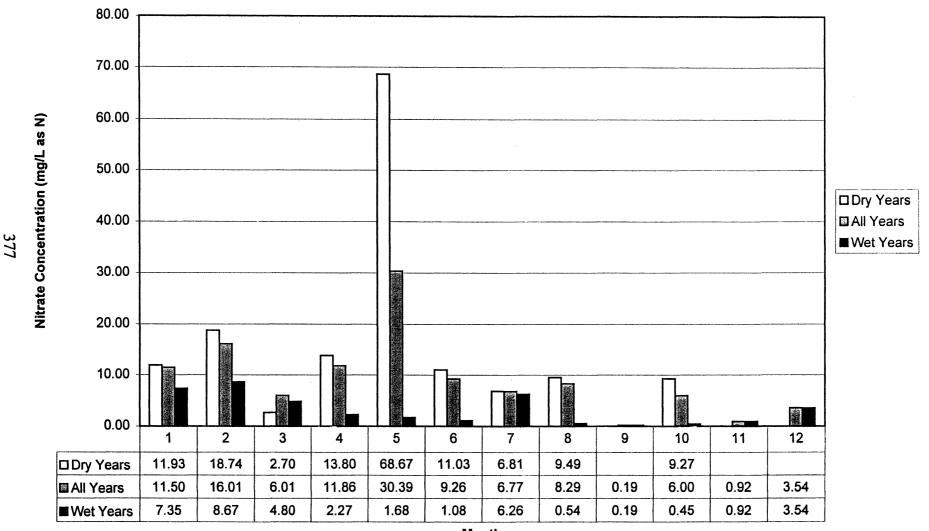
Nitrate at Sacramento R @ Mallard Is



Nitrate in Sacramento R @ Mallard Is



Nitrate in Delta Island Drainage



Nitrate in Delta Island Drainage

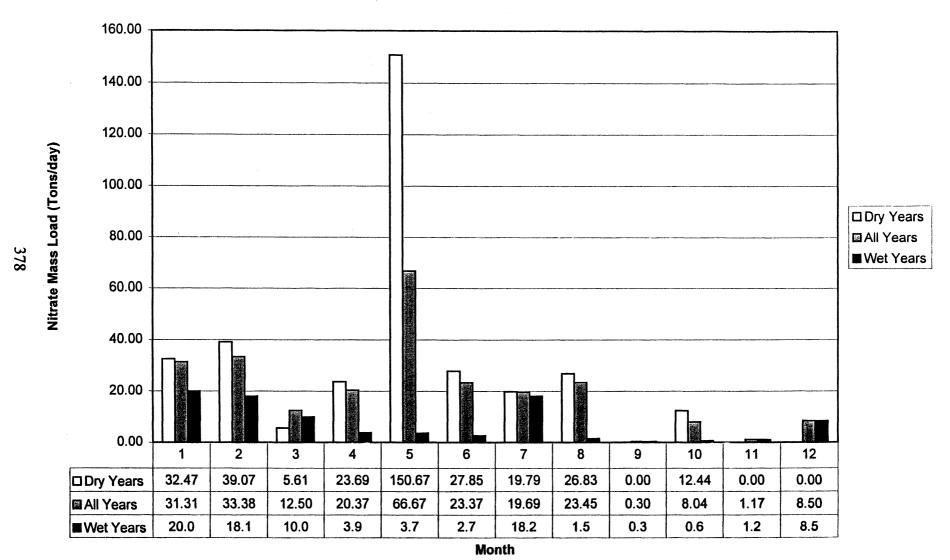
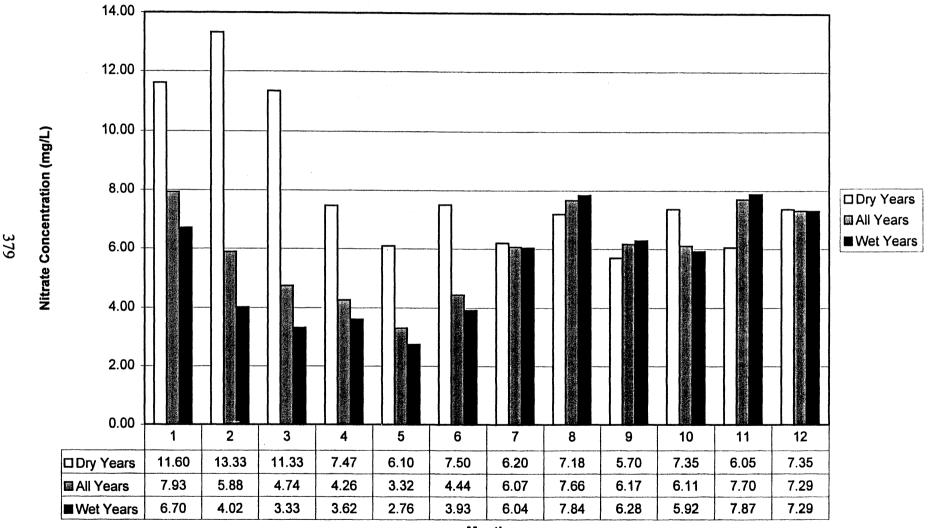
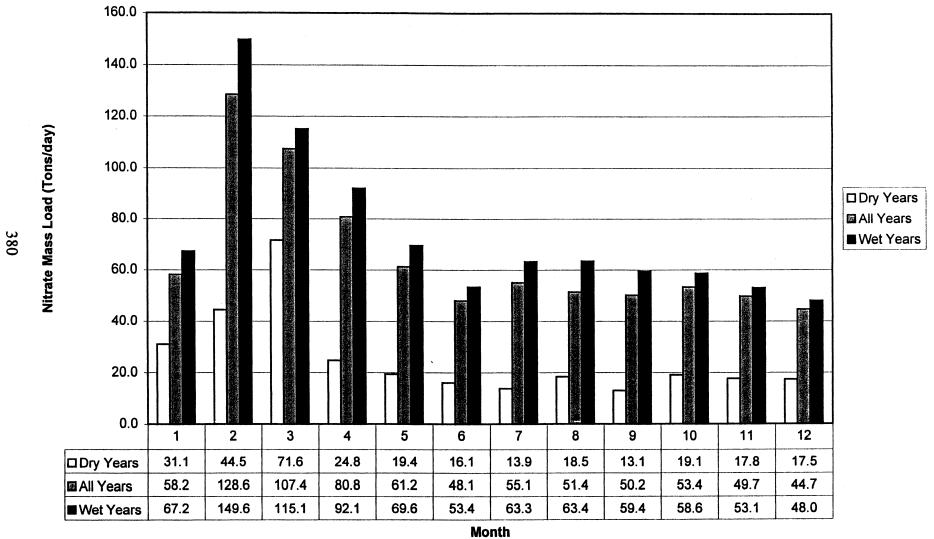


FIGURE A-12

Nitrate in S.J.R. nr. Vernalis



Nitrate in S.J.R. nr. Vernalis



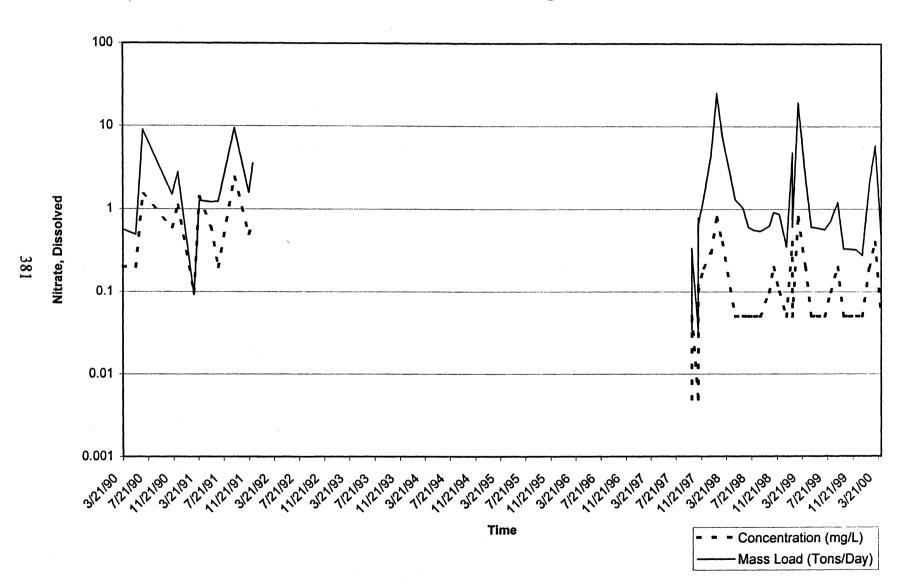


FIGURE A-15

Nitrate in American R @ WTP

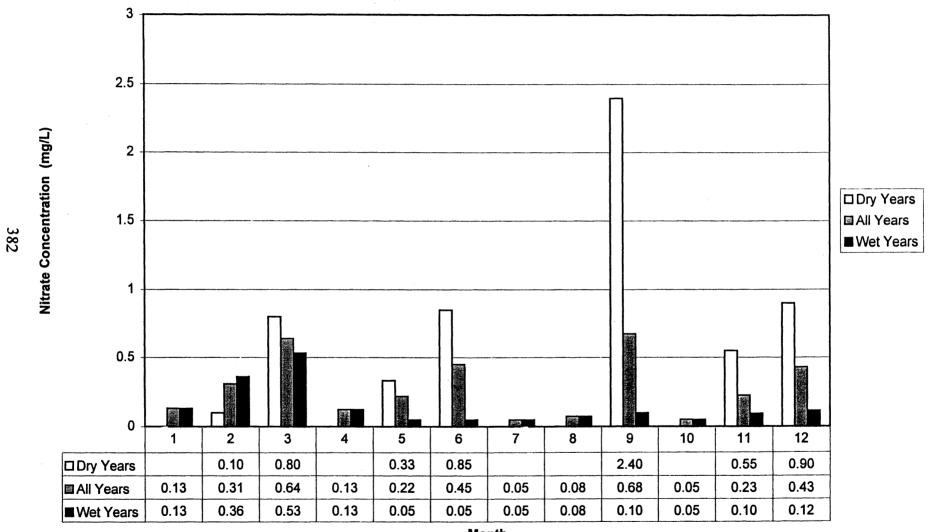
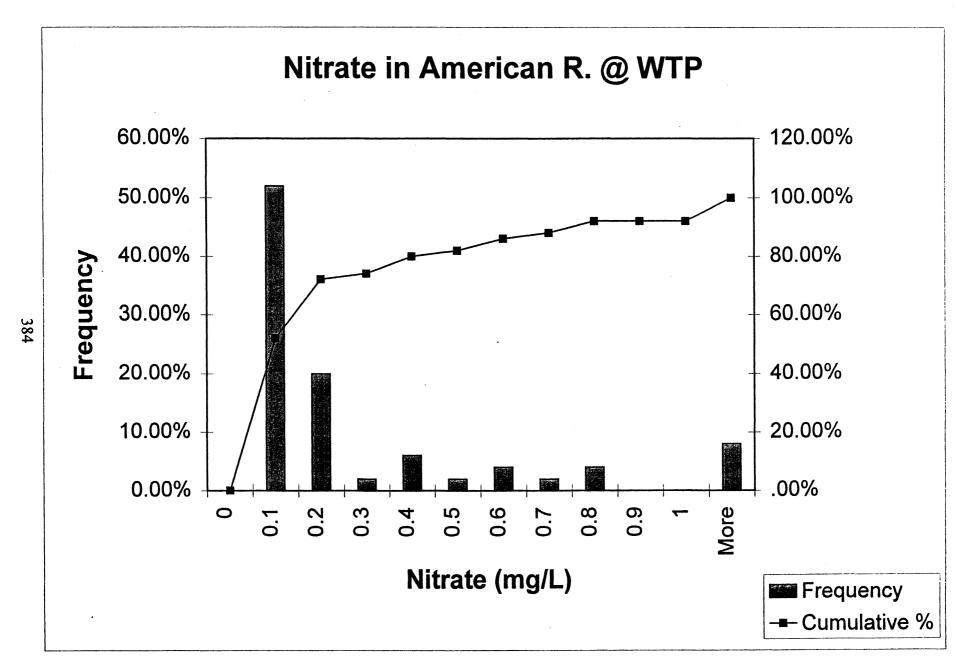


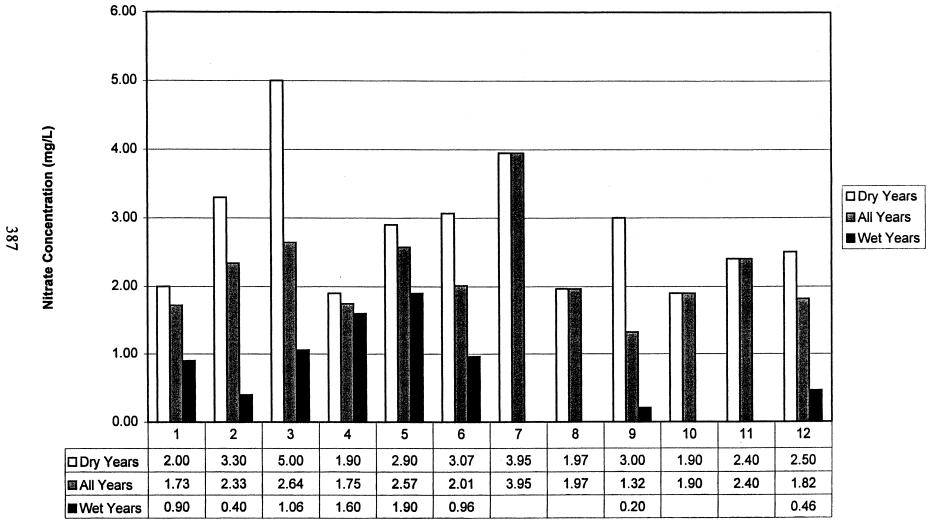
FIGURE A-17

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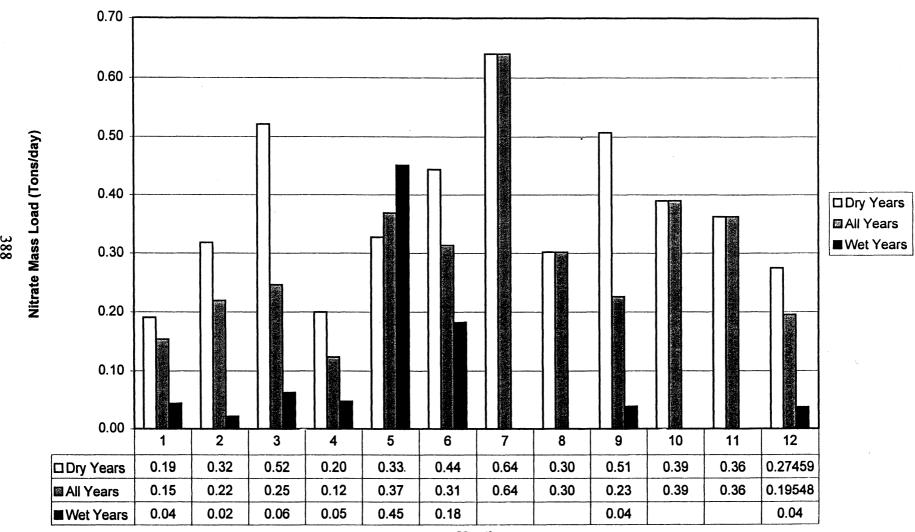


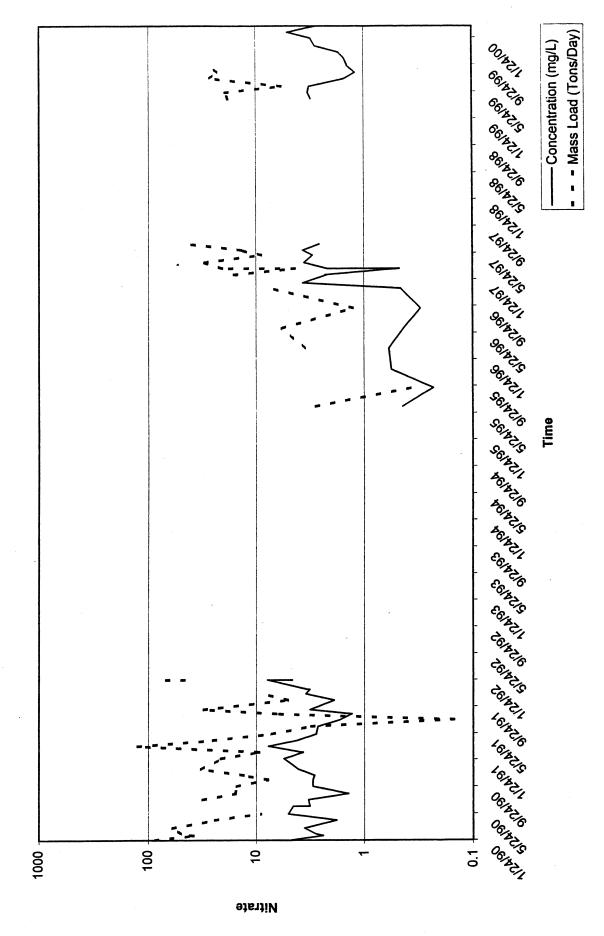
Nitrate at SWP N. Bay PP

Nitrate at SWP North Bay PP



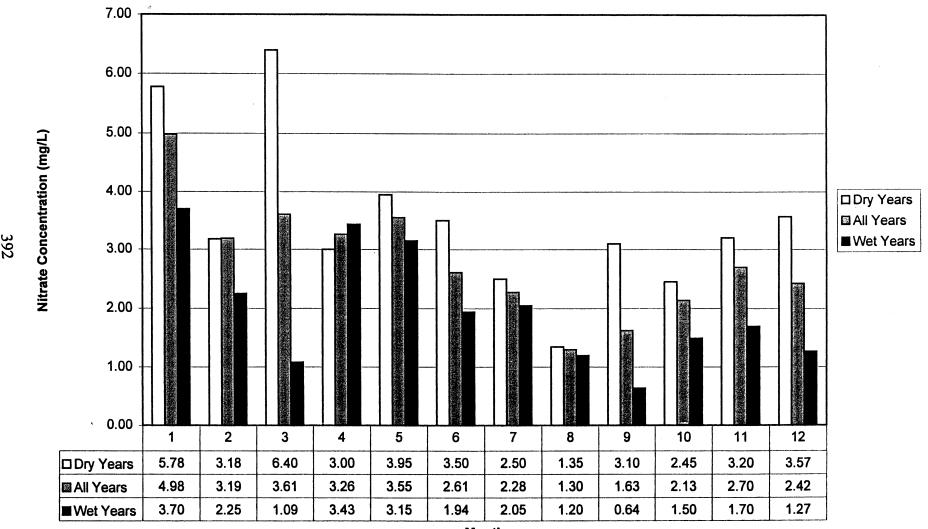
Nitrate at SWP North Bay PP



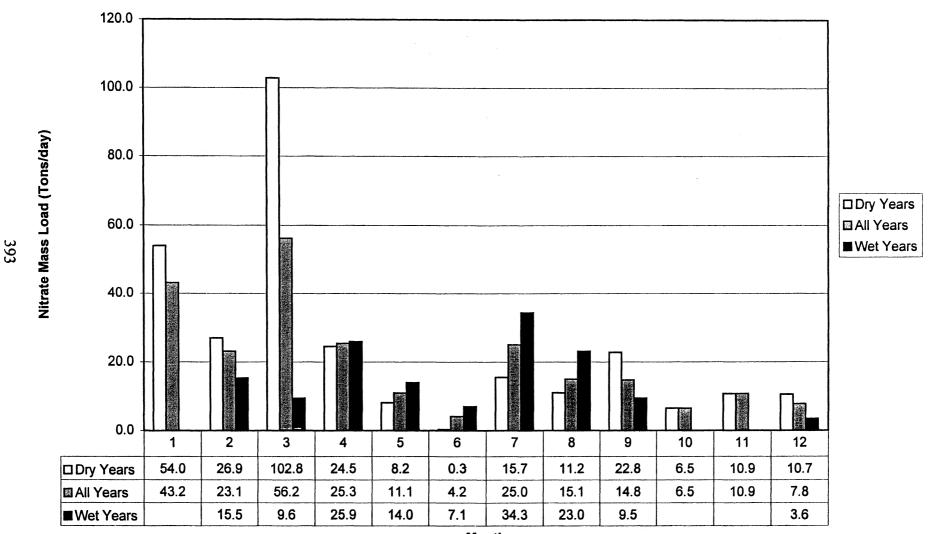


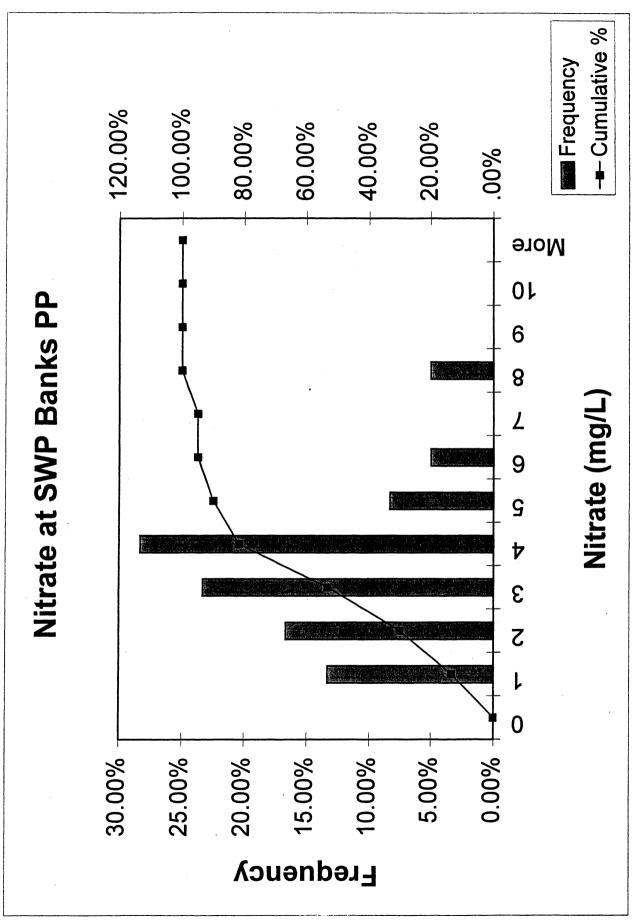
Nitrate at SWP Banks PP

Nitrate at SWP Banks PP

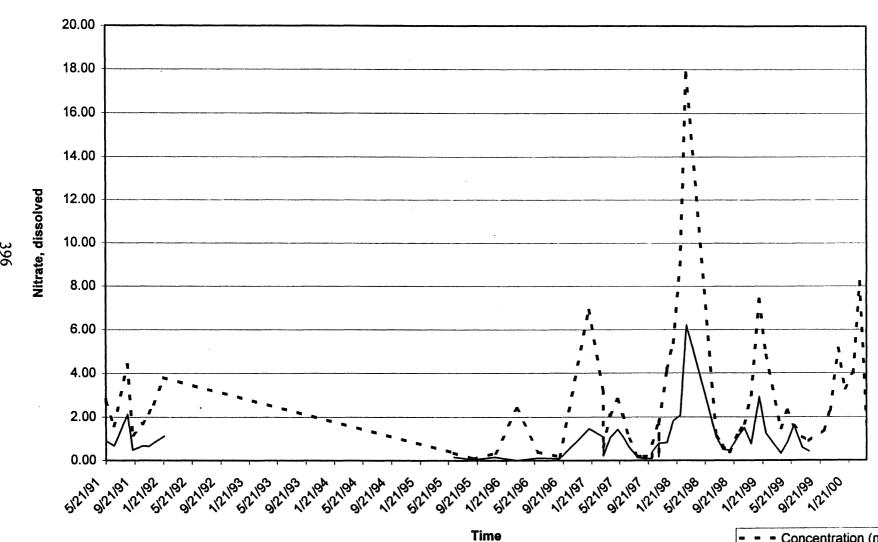


Nitrate at SWP Banks PP



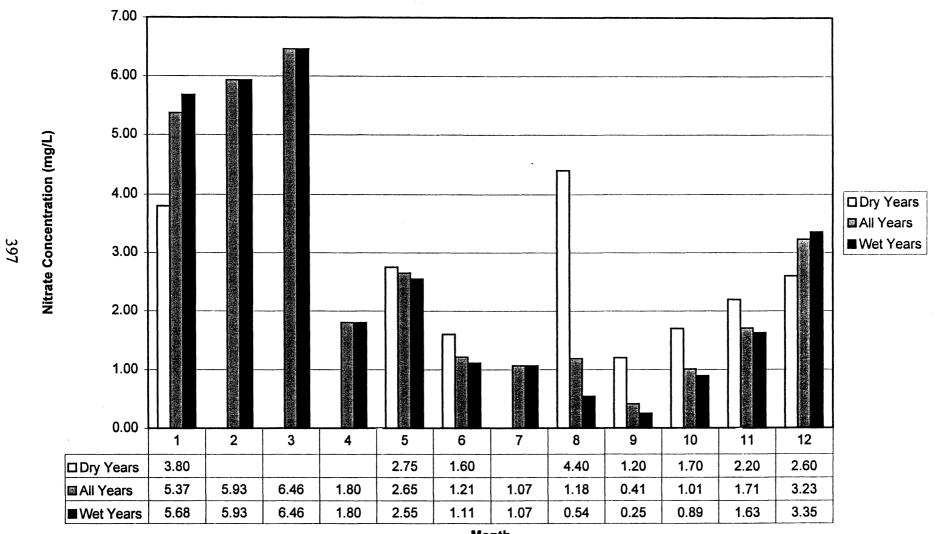


Nitrate at CCWD PP #1

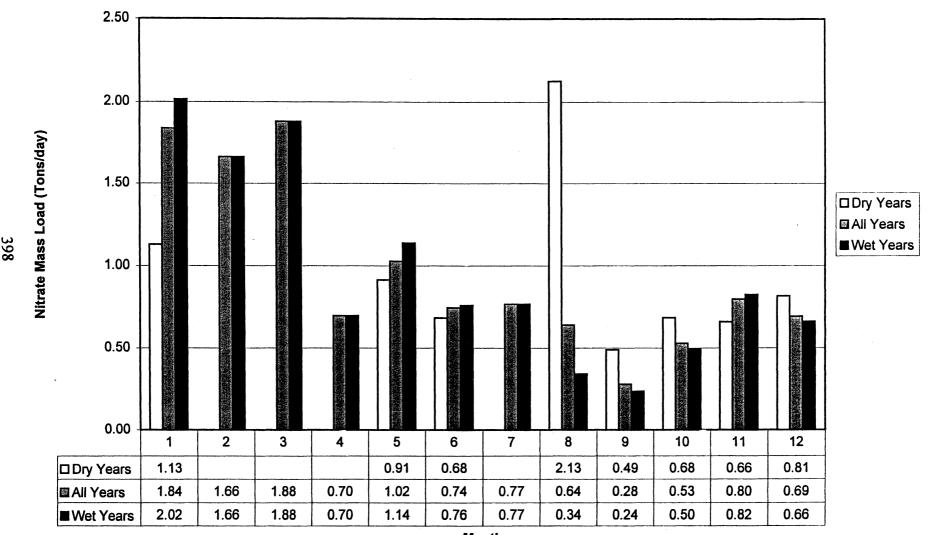


Concentration (mg/L) Mass Load (Tons/Day)

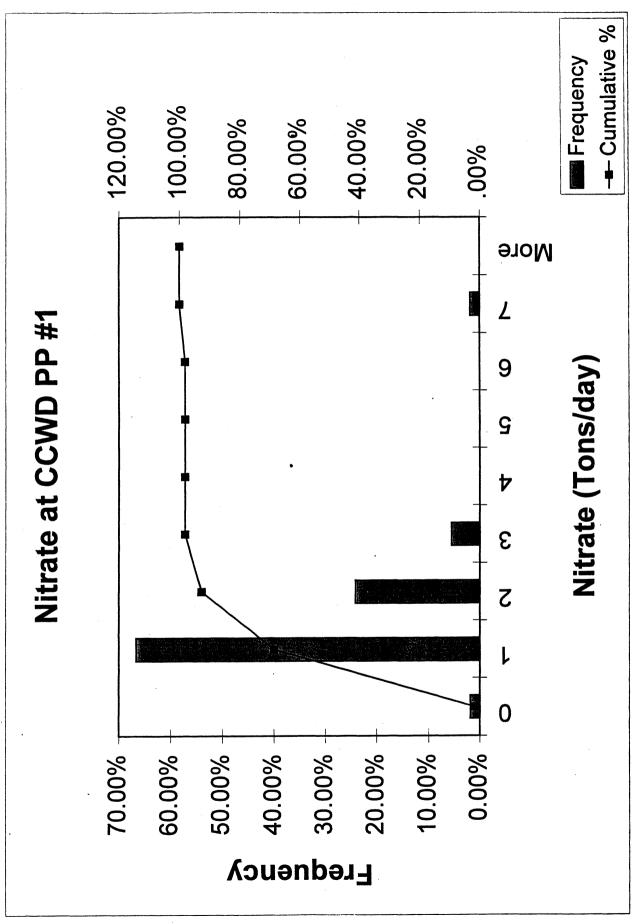
Nitrate at CCWD PP #1



Nitrate at CCWD PP #1



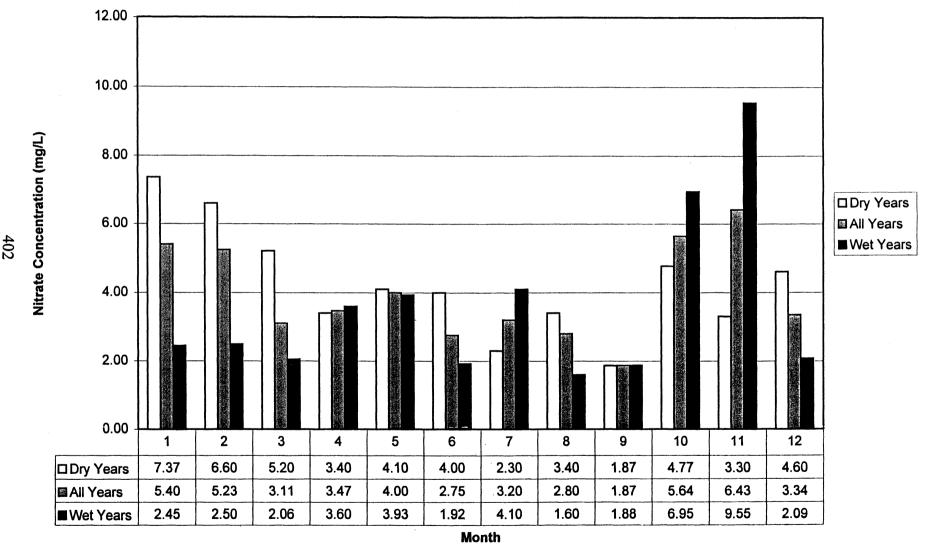
Month



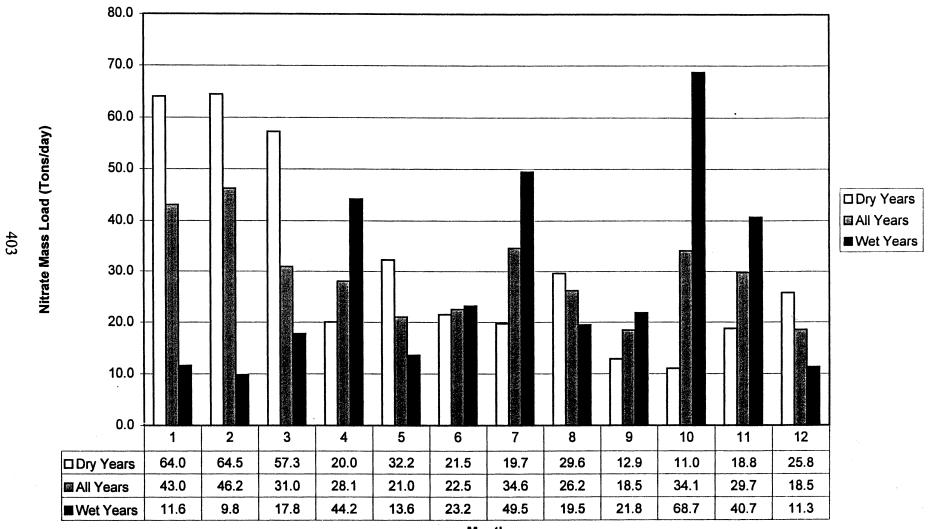
- Mass Load (Tons/Day) -Concentration (mg/L) 16 A2/6 TO WALS 10/82/1 SO MAZING 16/42/1 0.1 100 9 Nitrate

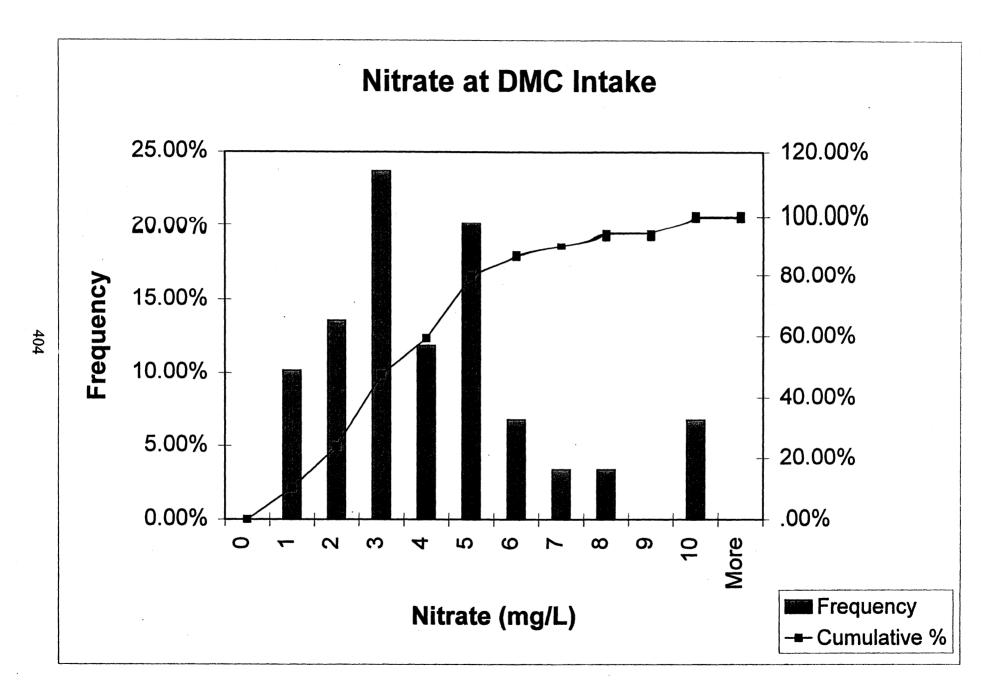
Nitrate at DMC Intake

Nitrate at DMC Intake



Nitrate at DMC Intake





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Sources and Magnitudes
of Water Quality Constituents of Concern
in Drinking Water Supplies
Taken From the Sacramento-San Joaquin Delta

Prepared for the CALFED Bay-Delta Program by Richard Woodard

September 22, 2000

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Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies Taken From the Sacramento-San Joaquin Delta

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List of Abbreviations and Acronyms

CALFED Bay - Delta Program, a partnership of State and Federal

agencies having responsibility for water supply, water system integrity, water quality, and ecosystem resources for the purpose of addressing the

problems of the Sacramento-San Joaquin Bay-Delta estuary.

CCWD Contra Costa Water District

CDEC California Data Exchange

cfs cubic feet per second

CVP Federal Central Valley Project

DBPs Disinfection byproducts – unwanted, and potentially harmful chemicals

produced by reaction of oxidants with organic carbon and bromide during

drinking water treatment.

D-DBP Disinfectants and disinfection byproducts

DMC Delta Mendota Canal, aqueduct of the Federal Central Valley Project

DOC Dissolved organic carbon

DWCWG CALFED Drinking Water Constituents Work Group. A group of drinking

water quality experts representing stakeholder interests who provide technical advice and assistance to the Delta Drinking Water Council, Bay-

Delta Advisory Council, and CALFED management

DWR California Department of Water Resources

EC Electrical Conductivity, more properly known as specific conductance, a

measure of the ease with which water conducts electrical current, which is

proportional the concentration of dissolved salts in the water.

EIS/EIR CALFED Programmatic Environmental Impact Statement/Environmental

Impact Report

EPA U.S. Environmental Protection Agency

Is Island

Ldg Landing

mg/L milligrams per liter

MWD Metropolitan Water District of Southern California

NTU Nephelometric Turbidity Units

PP Pumping plant

QA/QC Quality assurance/quality control

SJR San Joaquin River

SUVA Specific ultra violet absorbance, computed by multiplying UVA₂₅₄ reading

by TOC concentration, then multiplied by 100. This is an index that provides an indication of the ease by which organic carbon can be

removed through conventional water treatment processes.

SWP State Water Project

TDS Total dissolved solids, a measure of dissolved salts concentrations in water

supplies.

TOC Total organic carbon

USGS U.S. Geological Survey

UVA₂₅₄ Ultra violet absorbance at measured at a wavelength of 254 nanometers,

an indirect measure of organic carbon content

UVA See UVA₂₅₄

WTP Water treatment plant for production of drinking water.

WWTP Waste water treatment plant

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Introduction

The implementation phase of the CALFED Program (Phase III) officially began in August 2000 with the Notice of Determination and Record of Decision on the CALFED Programmatic EIS/EIR. Attainment of this important milestone will make state and federal funds available for accomplishment of CALFED objectives. These objectives will be achieved by implementation of projects to improve levee system integrity, restore the ecosystem of the Sacramento-San Joaquin Bay-Delta Estuary, improve water supply reliability, and improve water quality for all beneficial uses. The planned actions will include work to improve the quality of drinking water supplies taken from the Delta.

Objectives

Taken together, CALFED actions are expected to have profound effects on the Bay-Delta Estuary, including effects on the quality of Delta drinking water supplies. The effects of actions designed to improve drinking water quality must be measured in order to assure CALFED investments are successful and to enable the drinking water program to be managed efficiently. Also, actions directed at attaining other CALFED objectives, such as ecosystem restoration, may affect the quality of Delta drinking water supplies; ongoing assessments will have to be made to guard against adverse water quality effects resulting from such actions.

In order to identify water quality changes resulting from CALFED activities, it will first be necessary to establish existing (or baseline) water quality conditions in sufficient detail to make later comparisons possible. Accordingly, in preparation for the implementation phase of the program, the CALFED Delta Drinking Water Council, acting through its Drinking Water Constituents Work Group, have recommended a multi-faceted assessment program. The elements of this program include:

- Assessment of total organic carbon loads from the upstream watersheds to the Delta for water years 1980-1999;
- Real time monitoring for organic carbon in the Delta;
- High frequency multi-parameter monitoring at a key Delta location
- Database management to provide access to the information developed in these projects; and,
- Preliminary establishment of baseline water quality conditions through identification of sources and magnitudes of water quality constituents of drinking water concern.

The latter of these projects is the subject of this report. When completed, drinking water quality conditions will be known for the major stream inflows and discharges to Delta waters, for drinking water supply diversions from the Delta, and for the intakes of the major drinking water suppliers using Delta waters. As a first step, it has been intended that major existing sources of water quality and flow data would be used to define drinking water conditions in a preliminary way, in order to enable water quality improvement actions to be identified, and to develop data reflecting conditions existing prior to implementation of other CALFED actions.

It is anticipated that the initial effort would be followed by another study phase in which less readily available data sources are tapped and incorporated into a much broader analysis. A third, ongoing phase of this project will involve working with various water quality data collectors to encourage standardization of sampling and analytical methodology, adoption of uniform quality assurance/quality control procedures, and development of uniform data reporting formats. Through this approach, changing water quality conditions can be assessed on an ongoing basis through the joint efforts of many data collectors working in partnership.

In accordance with this vision, the current effort to establish preliminary baseline drinking water quality conditions can be envisioned as a snap-shot, whereas the longer term objective is to, in effect, create a motion picture. The data summaries presented here are intended to: provide a useful indication of major contributions of constituents of drinking water concern; to identify longer term trends and patterns of change; to help identify the need for follow-up studies; and, to provide an initial basis for developing a management program for water quality constituents of concern to drinking water supplies taken from the Delta.

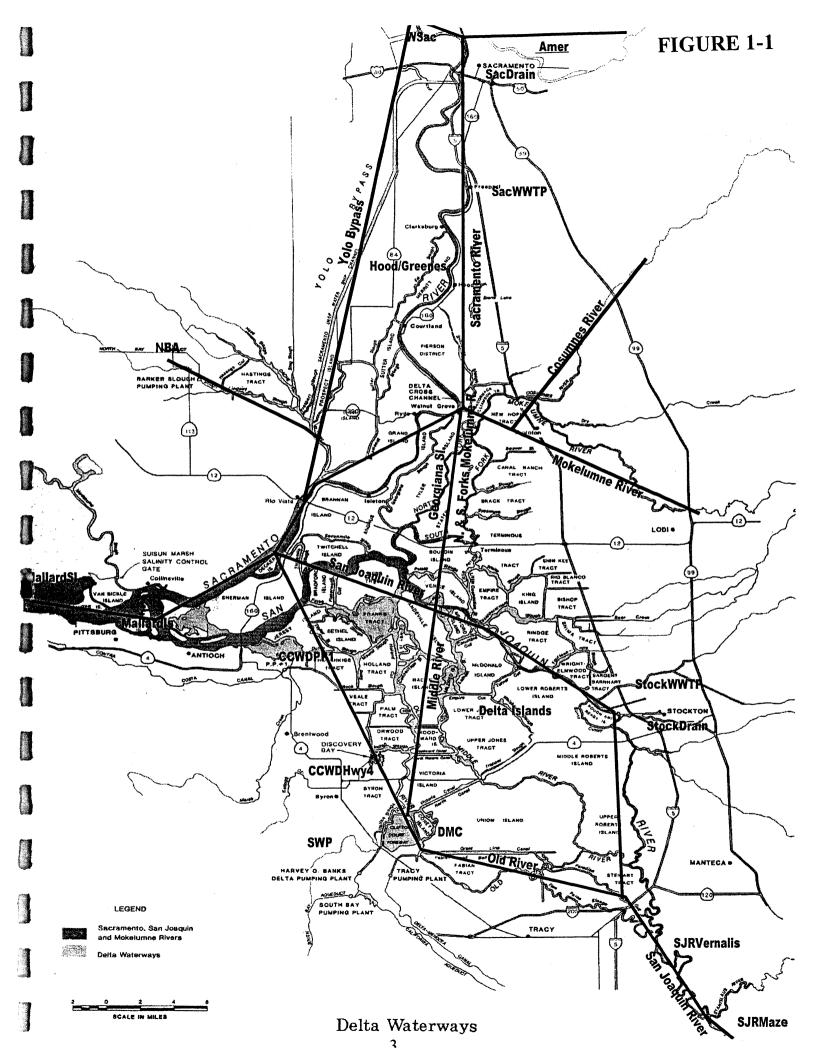
It is also important to understand the limitations of these presentations. Aggregated data summaries, such as those presented here, do not enable a sufficient understanding of day-to-day water quality fluctuations to enable operators of drinking water treatment facilities to function more effectively. It is not very helpful to a plant operator to understand long term trends if concentrations are sufficiently variable as to require chemical feed adjustments to be made daily. Nor, in most cases, will this information provide enough detail to enable corrective actions to be taken without further investigation. Information on overall water quality conditions and trends is rarely useful for identifying inputs of constituents that may occur over short periods, and that may result in concentration "spikes".

Study Area

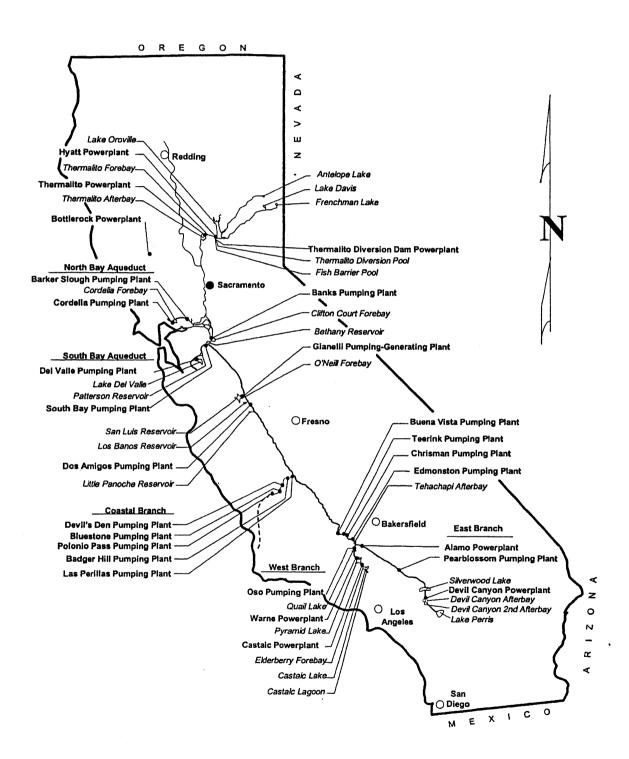
Figure 1-1 depicts the Sacramento-San Joaquin Delta, which is the focus of the current phase of the project. Superimposed on this map is a "stick drawing" that depicts in an abstract fashion, the main Delta waterways, and indicates the locations of major tributaries and discharges to the Delta, and diversions of drinking water supplies from the Delta. The stick figure will be used to depict water quality conditions for various parameters. This represents the core study area for this study phase, although upstream conditions in the most important tributaries to the Delta are also examined in some detail. Figure 1-2 is a representation of the State Water Project system that will also be examined in some detail.

Study Approach

The watersheds of the Sacramento-San Joaquin Delta occupy about one-third of the land mass of California. Human impacts caused by the presence of homes, past and present industries, and agricultural activities in these watersheds cover the spectrum of potential water quality pollutants. At the same time, about two-thirds of California's population drinks water taken, at least in part, from the Delta. The breadth of the spectrum of water



State Water Project Facilities



quality influences on Delta waters and the importance of the Delta for drinking water supply present a daunting challenge to adequately understand these influences and to appropriately protect consumers of drinking water taken from that source.

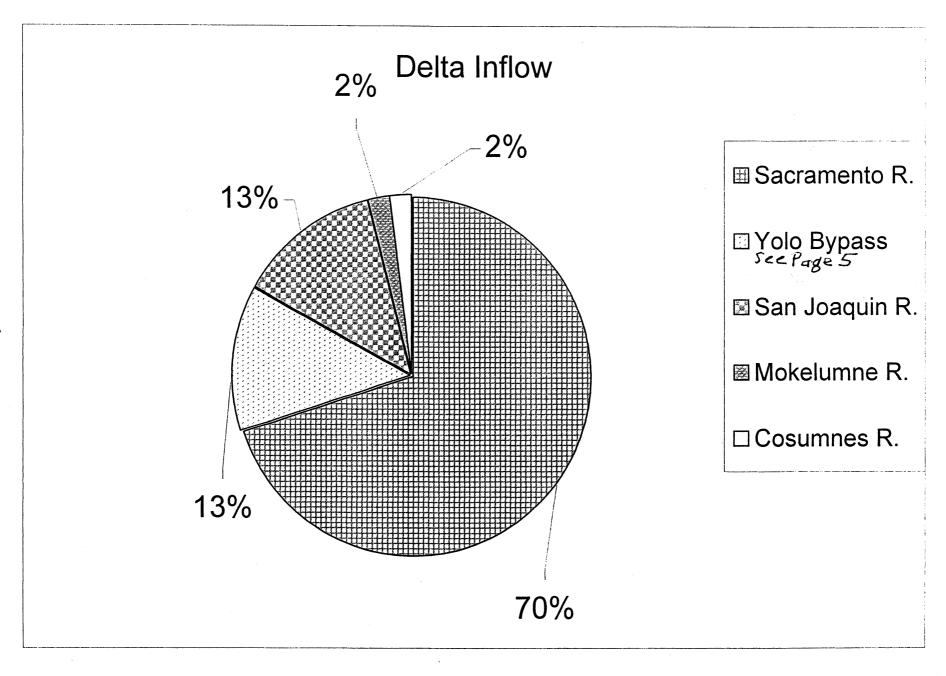
The job of fully characterizing all sources and magnitudes of constituents of concern for Delta drinking water supplies would be practically impossible due to the sheer scope of the task. A practical approach, therefore, is to begin with the largest sources and work toward the smaller as resources become available. An understanding of the relative magnitude flows into the Delta can provide some insight. Figure 1-3, which depicts overall stream flows into the Delta, indicates that the Sacramento River accounts for 70% of the water flowing into the Delta, whereas the San Joaquin River accounts for 13% and the Mokelumne and Cosumnes account for only 4% taken together. Yolo Bypass flows occur only during wet conditions; the Bypass shunts Sacramento River water to the western Delta where its influence on drinking water supplies is generally minimal.

The Sacramento and San Joaquin Rivers are overwhelmingly the most important stream inflows to consider with regard to water quality influence. This is particularly true when one considers that the quality of the Cosumnes and Mokelumne rivers is generally excellent with regard to drinking water quality constituents. Accordingly, this study focuses on the Sacramento and San Joaquin river inflows, with additional elaboration of upstream conditions where time and resources permit.

The primary waste water treatment plant discharges to the Delta are the Sacramento Regional County Sanitation District facility, located in the south area of Sacramento, and the City of Stockton waste water treatment facility in Stockton. Also of potential importance are storm drainage discharges from Sacramento and Stockton. Smaller cities upstream of the Delta, such as Redding and Modesto discharge treated waste water and storm drainage, but their distance from the Delta and relatively small magnitude of their discharges suggests the appropriateness of including these sources within the scope of a second, more intensive study phase. Consistent with the limited scope and duration of this study, treated waste water and storm drainage discharges into Delta drinking water supplies from the Sacramento region and Stockton are the focus of this study phase.

The primary drinking water suppliers diverting water from the Delta are the contractors using Delta waters through the North Bay Aqueduct, California Aqueduct, and South Bay Aqueduct of the State Water Project. Santa Clara Valley Water District takes drinking water supplies not only through the South Bay Aqueduct as a State Water Project contractor, but also through San Luis Reservoir as a Central Valley Project contractor. Contra Costa Water District takes its water supply through three Delta intakes located at Mallard Slough, Rock Slough, and Old River near Highway 4. The City of Tracy also takes drinking water supplies through the Delta Mendota Canal as a Central Valley Project contractor.

Ultimately, the quality of water supplied to each significant drinking water treatment plant using Delta waters will need to be characterized as part of this study; however,



consistent with the limited scope and duration of the initial phase of the project, drinking water quality conditions for these users can be assessed in a preliminary way by evaluating water quality at key points, including North Bay Pumping Plant (SWP), H.O. Banks Delta Pumping Plant (SWP), Tracy Pumping Plant (CVP), California Aqueduct, Check 13, SWP (outlet from O'Neill Forebay), Check 41, SWP (Tehachapi Afterbay – bifurcation of the East and West branches of the California Aqueduct), MWD diversion from Castaic Lake, SWP (terminous of West Branch, California Aqueduct) , and Devil Canyon Afterbay, SWP (terminous of East Branch Calfifornia Aqueduct)
These locations are the focus of current efforts to assess the quality of water received from the Delta by drinking water suppliers.

Recommendations

The following are recommendations stemming from this study.

- 1. This reconnaissance-level investigation was conducted over a short time with limited resources, and was intended as the first step in a process of information gathering to establish baseline water quality conditions. Time and resources were insufficient to accomplish detailed studies that were envisioned by the Drinking Water Constituents Work Group, such as evaluating the effects of Delta barriers. Further work should be done to accomplish all of the objectives envisioned by the group.
- 2. The reconnaissance-level study that is the subject of this report should be followed by more in depth study of the quality of water at the intakes of drinking water purveyors using Delta waters, and in storage reservoirs near intake points. Agencies treating Delta water should be approached for all relevant data, including nutrient and algal data, and these data should be subjected to a comprehensive evaluation to determine what quality changes occur after the water leaves the Delta and is supplied for treatment. Also, data collection programs for drinking water intake locations should be evaluated to determine their adequacy to measure changes that may come as a result of the CALFED program. Additional data collection should be sponsored at these locations as necessary.
- 3. In conjunction with detailed evaluations of data collected by drinking water purveyors at their intakes, a more thorough analysis of State Water Project water quality should be undertaken. This evaluation should include a preliminary effort to identify sources and magnitudes of drinking water quality constituents of concern at that location. The evaluation should also include recommendations for strengthening the SWP water quality program as necessary to fill any significant data gaps.
- 4. A number of data collectors, such as the Northern and San Joaquin Districts of DWR, have data that may prove useful in evaluating the quality of drinking water supplies taken from the Delta, but do not have the resources to make the data electronically available. CALFED should consider the feasibility of assisting these organizations to make their information available for analysis and interpretation by including the data in the comprehensive water quality database being sponsored through the CALFED program.
- 5. This reconnaissance-level study has revealed indications that should, in some cases, be followed up with further investigation leading to corrective actions. CALFED should establish a funding source for such studies. Detailed information development will prove crucial to enabling corrective actions to be identified, planned, and implemented.
- 6. Data relevant to the quality of drinking water supplies are largely lacking in the upper Sacramento River and San Joaquin Rivers. CALFED should consider

providing resources for collection of needed data by appropriate agencies, with guidance through the CALFED Program and its stakeholders.

- 7. Because of the importance of being able to use the historical quality and flow data generated at Greenes Landing on the Sacramento River and Vernalis on the San Joaquin River, a more intensive evaluation should be done to establish the comparability of data collected from the newer Hood and Mossdale monitoring locations.
- 8. In order to more firmly establish baseline water quality conditions, appropriate baseline hydrology should be developed to be used with measured water quality data to account for the effects of hydrologic changes in the Sacramento-San Joaquin Bay-Delta system.
- 9. This reconnaissance-level water quality evaluation should be considered the first step of a journey. In order to adequately assess the water quality effects of the CALFED program, a comprehensive network of water quality data collection must be established. Such a network can be most efficiently constructed by harnessing the efforts of the entities that already collect and use such data, modifying existing programs as necessary to accommodate CALFED needs. The whole should be bound together through standardized sampling and analytical methodologies and comprehensive, uniformly applied quality assurance/quality control procedures. As the first step of this process, the credibility and reliability of existing data on the quality of Delta drinking water supplies should be thoroughly assessed.

Data collected through these efforts should be stored electronically in a standardized format that will enable rapid acquisition and use of the data by those who need it. The objective should be to avoid the future necessity of having to spend half the resources available in a data evaluation project simply acquiring the data and rendering it into a useful format, as was the case with this study. Only when this data network is fully functional will CALFED have an assessment instrument that is sufficiently powerful to provide early detection of the nuances of change that will indicate success or failure of CALFED actions.

10. Because nitrogen and phosphorus nutrients change chemical form through oxidation/reduction and biological uptake, it is difficult to compare nutrient data from one location to another and over time using sample data alone. The Department of Water Resources' DSM2 model has the capability to model the nutrient cycle, but adequate data for calibration of the model is presently limited to the San Joaquin River in the Stockton area. Future nutrient monitoring conducted for CALFED should be integrated with DWR modeling efforts to strengthen model calibration. Modeling of nutrients throughout the Delta should be performed to enable a more complete understanding of nutrient sources and magnitudes, and factors affecting nutrient flux.

- 11. CALFED should continue and expand its support for continuous monitoring of key water quality constituents, such as organic carbon, ultraviolet absorbance, and electrical conductivity, along with flow at key locations. Data collected in this manner can often be made available to users in real-time, and can greatly improve the ability to characterize water quality changes spatially and temporally. On the basis of information yield per unit cost, continuous monitoring can also be extremely cost effective.
- 12. Water quality monitoring should be linked to, and coordinated with, mathematical modeling efforts on a continuing basis. This linkage will extend the usefulness of the data by enabling future conditions to be predicted, and to enable water quality predictions to be "normalized" to account for system changes over the periods of data collection, and to greatly refine computations of mass loadings. Modeling results derived from coordinated effort should also be used to help identify data gaps in the monitoring program, and to efficiently focus data collection efforts to provide maximum information yield.

Data Acquisition and Preparation

Acquisition and preparation of the data consumed about half the resources available for this project; however, this effort has produced data sets that will continue to be useful for various forms of analyses that may be needed later.

Data Sources

Water quality data were acquired from the following sources. UNLESS OTHERWISE NOTED, CHEMICAL ANALYSES ARE REPORTED IN DISSOLVED FORM:

USGS National Stream Water Quality Monitoring Networks (WQN)

USGS National Water Quality Assessment (NAWQA)

DWR Northern District - complete discrete sample data set

DWR, MWOI – complete discrete sample data set

DWR, Div. O&M, (State Water Project), grab sample and continuous recorder data, complete data set

City of Stockton Storm water

Interagency Ecological Program – continuous EC recorder data.

USBR – continuous EC data from Tracy PP

City of Stockton waste water treatment plant discharge

City of Sacramento storm water

Sacramento Regional County Sanitation District

Flow data were acquired from: Interagency Ecological Program California Data Exchange USGS (associated with WQN and NAWQA)

Data Preparation

The water quality data used for this project exists in a number of different formats. In order to render the information useful for performing equivalent analyses of different locations using data sets of different origin, it was necessary to transfer the data from its native format into a form that would readily permit analysis in this project. In some cases, data collectors had no unified database for their own use, which provided an opportunity to assist them by returning their data to them in a useful format.

Period of Record

CALFED predictions of water quality effects associated with the program are modeled using a 16 year period beginning with Water Year 1975 (that starts on 10/1/75). The need for consistency with other CALFED analytical efforts suggested that date as a logical start point for analysis in this project. The need for data to reflect recent water quality conditions, however, suggested the desirability of extending the period of interest beyond the 16 year period ending in 1991. Accordingly, through discussion with the CALFED Drinking Water Constituents Work Group, it was decided that the period of record of interest to this project is October 1, 1975 through most recent available. Of course, not all data sets used in the project were of that length.

Monitoring Locations

The following were the stream locations where water quality data were acquired:

American River at Sacramento Water Treatment Plant

Sacramento River at Verona

Sacramento River at West Sacramento Water Treatment Plant

Sacramento River at Hood

Sacramento River at Greenes Landing

San Joaquin River Near Vernalis

Cosumnes River at Dillard Road Bridge

Mokelumne River at Woodbridge

San Joaquin River near Vernalis

San Joaquin River at Maze Road Bridge

Tracy Pumping Plant (CVP)

North Bay Pumping Plant (SWP)

Clifton Court Intake (SWP)

H.O. Banks Delta Pumping Plant (SWP)

Santa Clara Terminal Tank (terminous of South Bay Aqueduct, SWP)

California Aqueduct, Check 13, SWP (outlet from O'Neill Forebay)

Check 41, SWP (Tehachapi Afterbay – bifurcation of the East and West branches of the California Aqueduct)

MWD diversion from Castaic Lake, SWP (terminous of West Branch, California Aqueduct)

Devil Canyon Afterbay, SWP (terminous of East Branch Calfifornia Aqueduct)

Delta Island drainage water quality data for about 25 Delta islands

Continuous electrical conductivity (EC) data from various Delta locations

Flow data were acquired from:

American River at Folsom

American River at Fair Oaks

Sacramento River at Verona

San Joaquin River at Vernalis

Stanislaus River at Ripon

Delta Island Drainage Flow (estimates by Dept. of Water Resources)

Sacramento Regional County Sanitation District discharge flows

Sacramento storm water drainage flow (estimates)

Stockton storm water drainage flow (estimates)

Stockton Waste Water Treatment Plant flows

State Water Project Pumping at various locations.

DAYFLOW data from Interagency Ecological Program (estimates of inflows to and outflows and diversions from the Delta)

Data Availability and Limitations

Not all data that would be desirable for this analysis were available, as may be expected. Where data were available, periods of record were sometimes shorter than would be desirable and/or non-overlapping in time with data from other locations. The reader

should be aware that non-matching data sets will, to some extent, compromise the power of the analysis.

Also, because sampling data represent actual water quality conditions present at the time of sampling, one must remember that use of historical data to establish baseline conditions can be misleading. Many changes are underway in the watersheds tributary to the Delta and in the Delta itself. Increased urbanization and urban discharges, changing water use patterns, changing water project operations, changing agricultural practices (such as implementation of reduced tillage technology and changing crop patterns), and efforts by local entities to prevent and control water pollution are examples. Many of these changes may affect the quality of drinking water supplies taken from the Delta.

If one analyzes water quality data over a period of time, general trends will tend to emerge that contribute to quantifying current conditions against which future changes will be measured. Unfortunately, however, such an analysis is complicated by the fact that, during the period over which the analysis occurs, changes in the system have been ongoing, and these changes introduce error to the computation. Therefore, to truly establish a baseline, it is necessary to "normalize" the data by accounting for the water quality changes that occurred over the period of analysis. Mathematical models are an appropriate tool for making such computations; such an effort may be appropriate in a subsequent phase of this study.

Use of Specific Conductance (EC) for estimating total dissolved solids and bromide. Specific conductance, also known as electrical conductivity or EC, is an inverse measure of the resistance of water to the passage of electrical current. EC is linearly related to the presence of salts in the water, with higher salt concentrations resulting in higher EC's. Total dissolved solids (TDS), a direct measure of overall salt content, is closely related to EC in most waters. And, in Delta waters, bromide concentration can generally be predicted with some accuracy by use of EC measurements. The salinity section of this report discusses the relation of EC to TDS, and presents evidence that use of regression equations to predict TDS based on continuously recorded EC is probably superior to using discrete sample data for that purpose, all else being equal.

To enable the use of EC as a surrogate for TDS and bromide in this study, linear regression analyses were performed using discrete samples collected at various key Delta locations where continuous recording devices are installed. The regressions were performed using data collected through DWR's Municipal Water Quality Investigations Program, and are used to predict TDS and bromide in the San Joaquin River near Vernalis, at Tracy Pumping Plant, and at H.O. Banks Delta Pumping Plant, as opposed to relying only on sample data for these locations.

Quality Assurance/Quality Control

Ideally, only data sets that are identical in every respect would be used for comparing different time, locations and water quality constituents. A very important aspect of data comparability is the strength of the quality assurance/quality control programs that support data collection efforts. Entities such as the U.S. Geological Survey and

California Department of Water Resources have QA/QC programs that improve the reliability of data reported by these agencies. Other collectors may or may not have implemented adequate programs.

In a subsequent phase of this project, the QA/QC programs supporting all sources of data being employed for analysis need to be rigorously evaluated, and limitations on the usability of existing data sets should be specified based on the results of the evaluation. The limited scope of this phase of the study will allow no more than identifying the data producers whose programs do incorporate QA/QC, and attempting to rely most heavily on data from these sources. Fortunately, the richest sources of drinking water quality data in the Delta are DWR and USGS, so these sources were used in preference to others, pending a more rigorous evaluation.

Report Organization

This report is organized according to the individual parameters that were identified by the CALFED Drinking Water Constituents Work Group as being of concern in drinking water supplies taken from the Delta. Discussion of each constituent begins with an overall perspective on the quantities of materials entering the Delta system, followed by:

- Spatial comparison overall concentrations and loads of materials entering and leaving the system.
- Historical trends changes in constituents over time at key locations.
- Seasonal and hydrologic trends concentrations and mass loads at key locations arrayed by month, during all years taken together, for dry years (below normal, dry and critically dry), and for wet years (above normal and wet).
- Cumulative frequency analyses frequency distributions of concentrations and loads.

The water quality constituents addressed in this analysis are:

- Disinfection Byproduct Precursors substances that react with drinking water disinfection chemicals to produce unwanted and potentially harmful chemical byproducts of the disinfection process.
 - o Total/Dissolved Organic Carbon reacts with some oxidant chemicals (chlorine, ozone) to produce halogenated organic compounds that can be of health concern. Drinking water suppliers using source waters containing over 2.0 mg/L organic carbon must undertake additional efforts to reduce the potential for forming disinfection byproducts during treatment.
 - o UVA₂₅₄ (an indicator of organic carbon content)
 - o Bromide (bromide reacts to produce brominated disinfection byproducts that potentially can be more harmful and/or difficult to treat than non-brominated disinfection byproducts.) Bromide is a salt which, in Delta waters, is believed to be primarily of of sea water origin, as a result of seawater intrusion into the Delta fresh water system. Bromide is discussed in the disinfection byproduct precursors section of this report owing to its significance to human health. However, from the perspective of its origins and behavior in the Delta system, it is also appropriate to think of bromide as a salinity component. This should be remembered when the reader encounters the salinity discussion.
- Salinity salts degrade the quality of Delta waters for all beneficial uses, including drinking water.
 - Total Dissolved Solids a physical measure of overall salt content, for which a drinking water standard exists
 - o Chloride in elevated concentrations, produces a salty taste, and for which a drinking water standard exists.
 - Sodium contributes to health problems in sensitive persons when present in elevated concentrations in drinking water. A drinking water standard exists.

- Nutrients Nitrogen and phosphorus compounds are the primary nutrients supporting growth of algae in Delta waters, and in conveyance facilities that transport Delta water to drinking water suppliers. Algae can be a source of organic carbon that promotes formation of potentially harmful disinfection byproducts during drinking water treatment. Also, algae are capable of causing physical obstructions of water conveyance systems, clogging filters used for drinking water treatment and, perhaps of most concern to drinking water supply agencies, causing taste and odor in consumers' drinking water. From the standpoint of drinking water supply, the less nutrients the better. (By contrast, some ecologists believe increased nutrients in the Bay-Delta estuary would promote desirable fishery conditions.)
 - O Nitrogen compounds: ammonia, nitrite, nitrate, and organic nitrogen are forms of nitrogen that may be present in Delta drinking water supplies, and for which some data are available. These are discussed.
 - o Phosphorus compounds: data for ortho-phosphate and total phosphorus were available and were examined.
- Turbidity affects water treatment processes by contributing to filter clogging, and by shielding pathogenic organisms from disinfectant chemicals. Unlike dissolved salts, most forms of turbidity caused by particulate matter in the water are not persistent in the system, and tend to settle out as water velocities decrease. Yet, the availability of data and concern over turbidity effects suggested the need to analyze the available information.

Organic Carbon

Organic carbon is a critical building block for production of chemical byproducts of drinking water disinfection, along with bromide and chemical oxidants (chlorine, ozone) used for disinfection. Disinfection byproducts (DBPs) can be formed in the absence of bromide, but not in the absence of carbon. Most of the organic carbon that reacts with oxidants to form DBPs is in dissolved form, and that is the reason drinking water purveyors are interested in knowing the concentration of dissolved organic carbon (DOC) in their source waters. Current federal and state drinking water regulations (Stage I Disinfectants-Disinfection Byproducts Rule) require monitoring of drinking water sources for total organic carbon (TOC) and, if concentrations are regularly greater than 2.0 milligrams per liter (mg/L), the agency treating the water must evaluate means of enhancing the treatment process to optimize TOC removal. Therefore, both DOC and TOC are of concern to agencies supplying treated drinking water.

DOC is measured by filtering water samples using 0.45 μ m membrane filters. Thus, DOC is defined as organic carbon that passes through the filter. TOC is measured on unfiltered samples. Based on data collected by the Department of Water Resources, the DOC of fresh water inflows to the Delta through the American, Sacramento, and San Joaquin River averages 94% of the TOC, an indication that most of the organic carbon present in Delta inflow streams is in dissolved form. (The relationship is, however, variable. A regression analysis produced an R Square of 0.5, indicating that the 94% conversion factor should cannot be used a reliable predictor of DOC based on TOC.

Organic carbon is created primarily by plant photosynthesis. When vegetation decays, large humic and fulvic acid morecules are produced that subsequently enter water courses. It is these complex organic compounds that are believed to contribute most to the presence of DBP forming organic carbon in drinking water supplies.

Dissolved Organic Carbon

Filtration is among the most important processes used for drinking water treatment. Well designed and efficiently operated filter systems are capable of removing most particulate matter, producing water that is low in turbidity and low in particulate organic carbon. DOC can be removed to some extent as well through coagulation, sedimentation and filtration processes; however, DOC is less efficiently removed than is particulate organic carbon. Moreover, DOC is typically more reactive than TOC in forming DPBs. DOC concentration in the water is, consequently, a more reliable predictor of DBP forming capacity than is TOC, which is the reason much of the available data in the Delta and its tributaries is for DOC.

Delta Tributaries

Figure 2-1 summarizes the relative magnitudes of DOC mass loads in the main tributaries to the Delta. Figure 2-2 provides a spatial representation of concentrations and loads in the Delta area. Although the concentration DOC in the Sacramento River is lower than is the case for the San Joaquin River, its larger flow causes the load from the Sacramento to predominate, being nearly three-quarters of the total inflow load. The San Joaquin and American Rivers are next in size of load, comprising 20 percent and 9 percent,

Sacramento ■ American DOC Loads in Tributary Inflows **All Years** %0-%0-

■ Mokelumne

Cosumnes

(est.)

respectively. The Sacramento Regional and Stockton waste water discharges contribute to the DOC load into the Delta system, but DOC data are unavailable for these sources.

Drainage from Delta islands, particularly from islands with highly organic peat soils, contributes significantly to the DOC load in the Delta, with and average DOC concentration of 17 mg/L, and an estimated loading of 36 tons/day. This load is, however, not purely produced on Delta islands, in that the water diverted onto Delta islands contains DOC that may be concentrated by evaporation and plant transpiration. DOC produced as a result of leaching of DOC from organic soils adds to the concentration in island drainage, and some DOC is lost from the system by volatilizing into the atmosphere and, perhaps by being incorporated into living processes or bound by soils or other matter.

DOC concentrations in drinking water diversions from the Delta are nearly twice those in the Sacramento River, reflecting inputs from many sources, probably including algal growth in Delta channels.

The Cosumnes and Mokelumne Rivers are not significant contributors due to their good quality and relatively low flows.

The North Bay Aqueduct of the State Water Project experiences DOC concentrations that are significantly higher than are found at other locations. Studies by the Department of Water Resources have provided evidence that the local watershed is a major contributor.

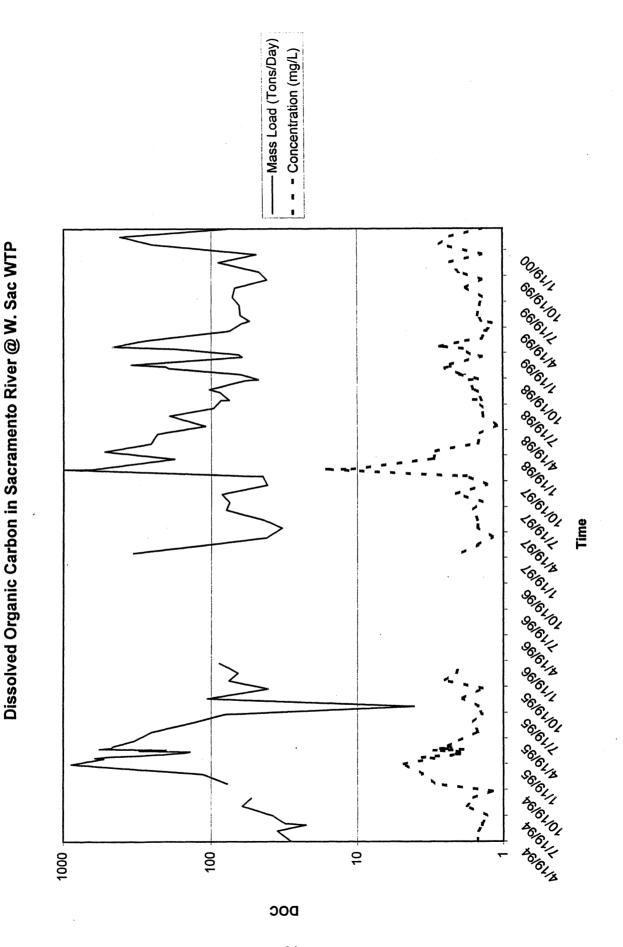
The following is a discussion of DOC conditions at specific locations.

Sacramento River As the largest fresh water inflow to the Delta, the Sacramento River is the tributary having greatest overall influence on the quality of Delta waters. However, other tributaries, especially the San Joaquin River, can have pronounced effects on the quality of nearby water bodies.

West Sacramento Intake

Figure 2-3 depicts historic DOC concentrations measured at the intake to the City of West Sacramento's drinking water treatment plant, located near the Interstate 80 bridge over the Sacramento River in West Sacramento. Neither the concentration or load curves demonstrate obvious long term change; variability tends to be rather high, with wet periods generally being associated with higher DOC concentrations and loads. The highest concentration measured was in December 1997 when river flow was about 22,000 cfs. The explanation for this unusually high result is unexplained. Duplicate field samples were taken on that occasion, and both were consistent, providing an indication that the readings were accurate.

Figure 2-4 depicts monthly average DOC concentrations for dry years (below normal, dry, and critically dry), all years taken together, and wet years (above normal and wet). This summary demonstrates a typical pattern of higher DOC concentrations corresponding to wet months and wet years. These data provide support for an



hypothesis that the most important contribution to DOC in Delta inflows is from surface runoff from the soils of the watershed. According to this hypothesis, plant growth during the warm growing season, and subsequent seasonal degeneration and decay is an annual cycle that makes soluble carbon compounds available for dissolution and transport during the wet season. DOC data from this location has been collected only since 1994, which included only one critically dry year, with the remainder being wet. The data should not, therefore, be assumed to represent a full hydrologic range.

Figure 2-5 shows DOC mass loads at the West Sacramento location on the Sacramento River. This graph shows pronounced increases (up to 7-fold) in DOC loads during wet months.

Figure 2-6 is a cumulative frequency graph that shows that nearly all measured concentrations are at or below 3 mg/L, with most falling in the 1.5 mg/L to 1.8 mg/L range. The similar graph for mass loading, Figure 2-7, demonstrates that, while loads of up to 1000 tons per day have been observed, more common are loads in the 50 to 500 tons per day range.

Greenes Landing

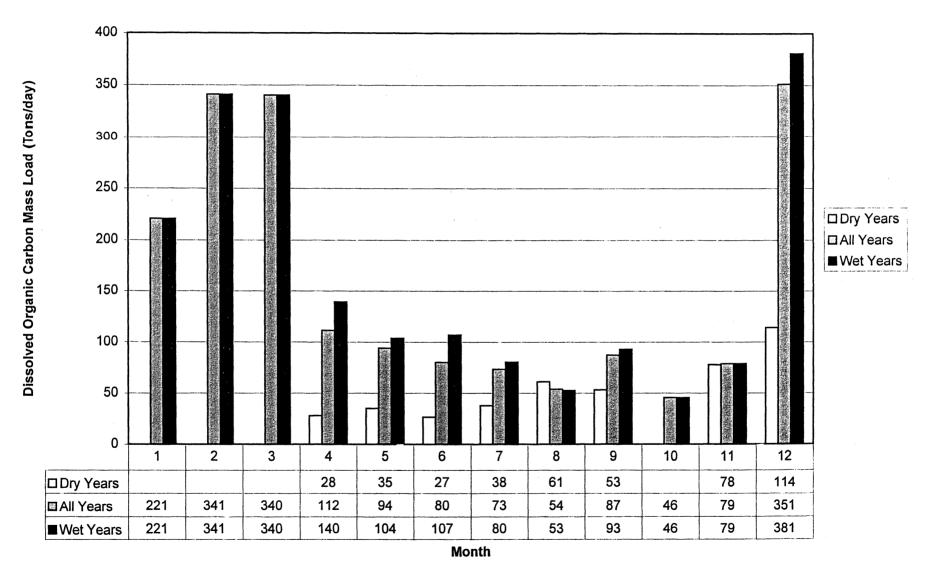
Figure 2-8 presents a historical depiction of DOC concentrations and loads in the Sacramento River at Greenes Landing, located about 8 miles below the Freeport Bridge. This location is downstream of the confluence of the American River and downstream of the Sacramento Regional Waste Water Treatment Plant, and is in the general vicinity of the location where a connection to the Mokelumne River could be built as part of the CALFED program. Data from 1989 to recent demonstrate no obvious trends of change.

Figure 2-9 shows monthly mean DOC concentrations, along with the range encompassed within one standard deviation above and below the mean. Februaries tend to be highest, while Aprils tend to be lowest in DOC, on average. Figure 2-10 shows monthly DOC mass loads, and the range of one standard above and below the mean. As is true for concentrations, mass loads tend to be highest in Februaries. Mass loads tend to be lowest in the fall periods when river flows are lower.

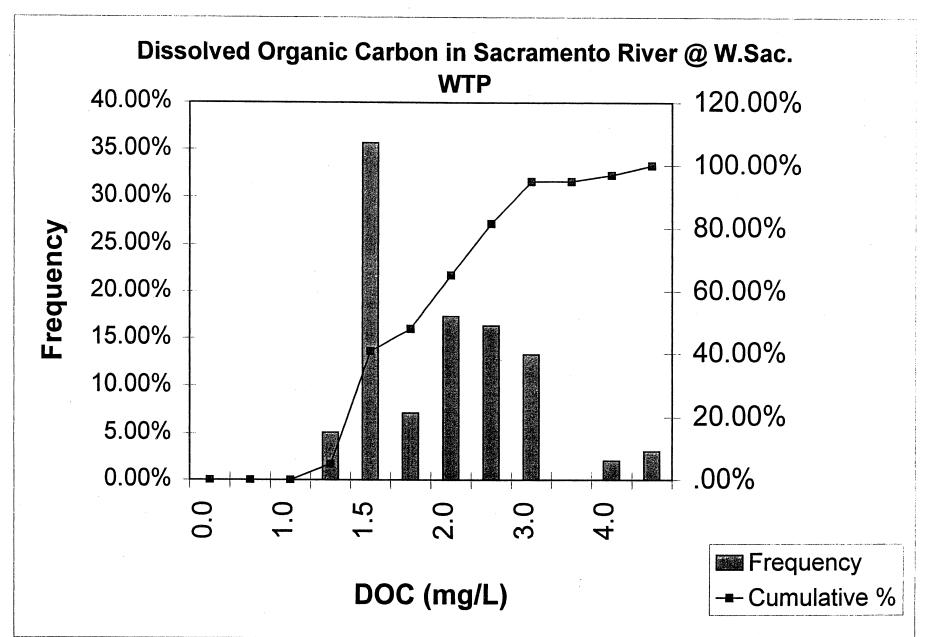
Figure 2-11 shows average monthly DOC concentrations during different hydrologic conditions. Dry months of wet years are characterized by the lowest DOC concentrations, with the opposite being true for dry months of dry years. This pattern is dissimilar to that observed at the West Sacramento Intake location. The difference may be related to the additional water quality influences that are reflected at the downstream location, and to the fact that the period of record for the West Sacramento location is considerably shorter.

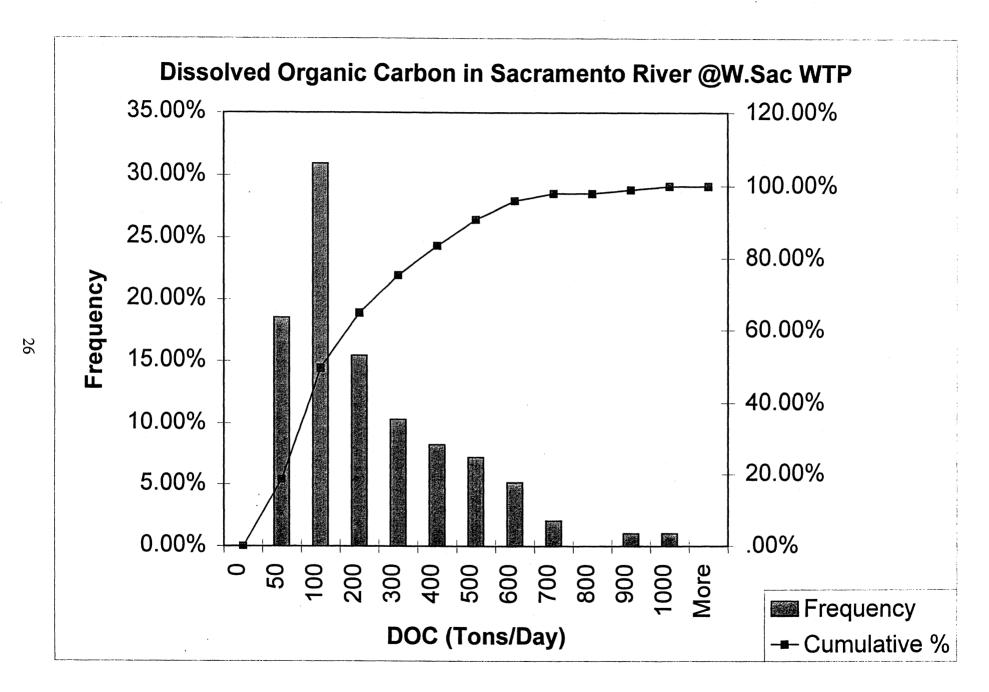
DOC loads, as depicted in Figure 2-12, are generally similar to those observed at the upstream monitoring location, with wet months of wet years being predominant. Figure 2-13 and Figure 2-14 are frequency distributions indicating 80% of observations are in the 2 to 4 mg/L range, while a similar percentage of loads fall within the 100 to 300 tons/day range.

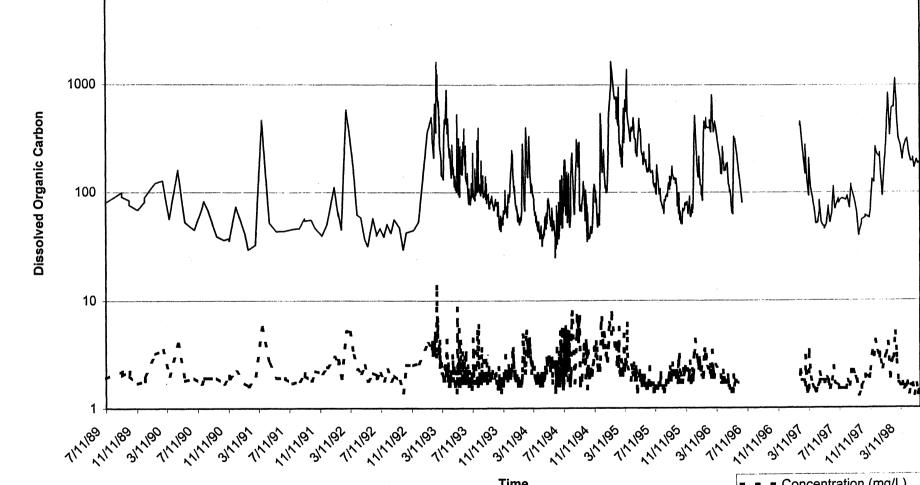
DOC in Sacramento R @ W. Sac. Intake









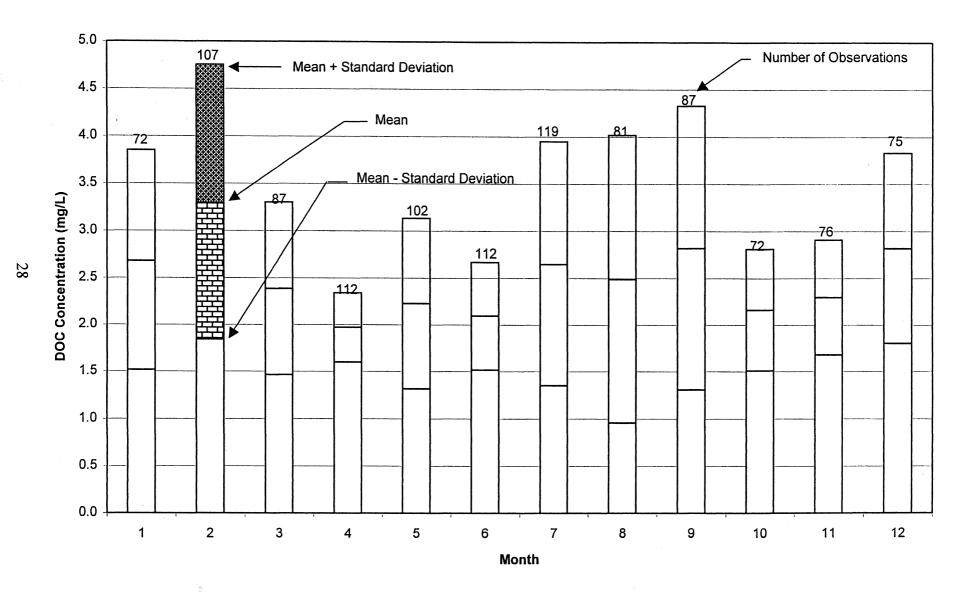


Time

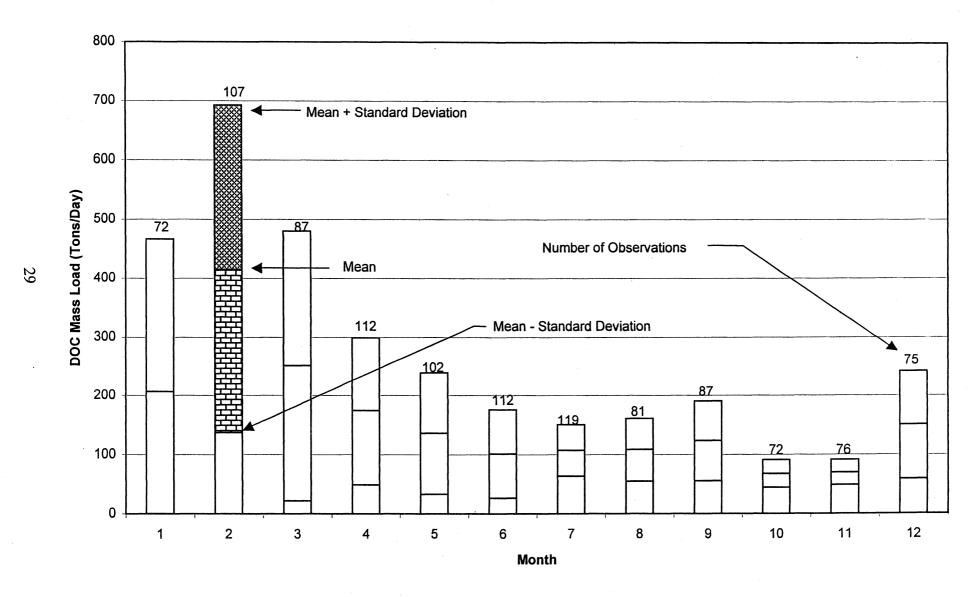
10000

Concentration (mg/L) Mass Load (Tons/Day)

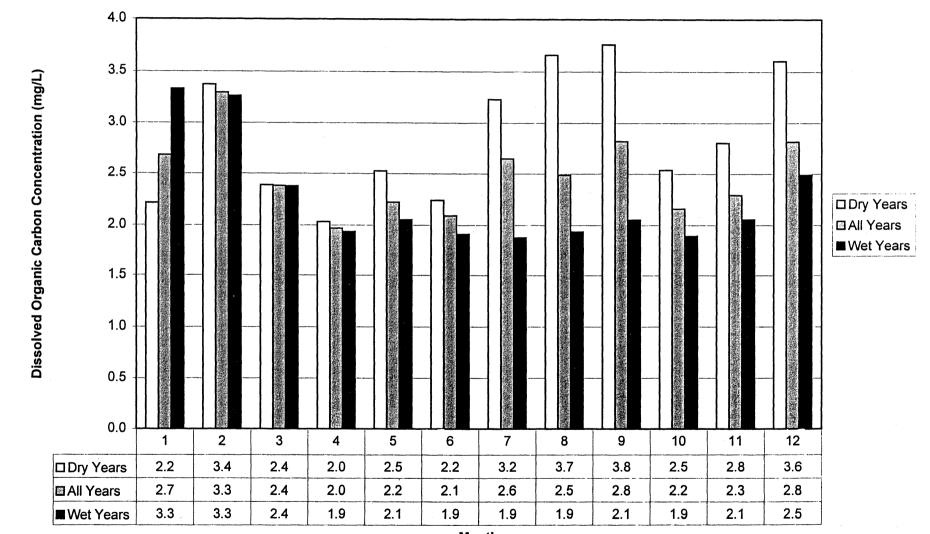
Dissolved Organic Carbon in Sacramento R @ Greeens Ldg



Dissolved Organic Carbon in Sacramento R @ Greenes Ldg

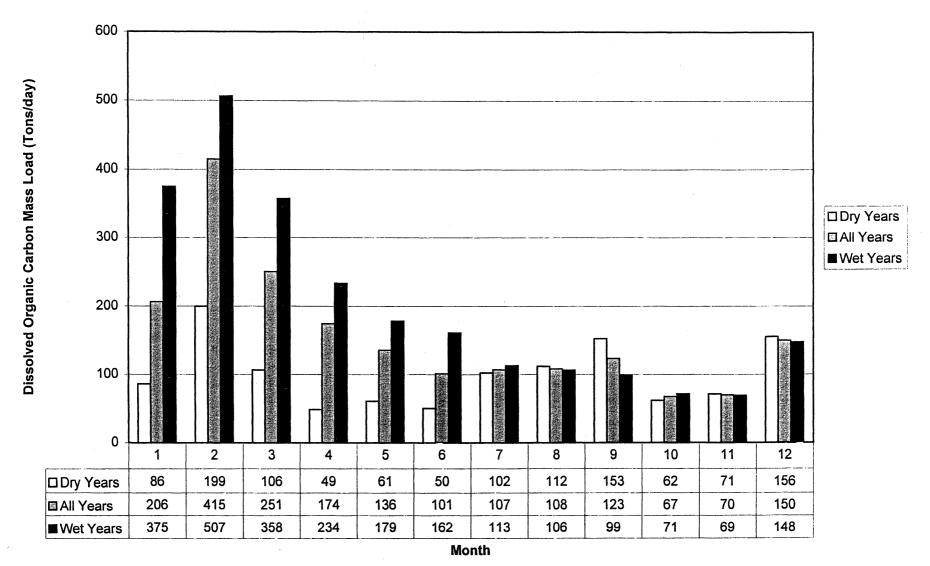


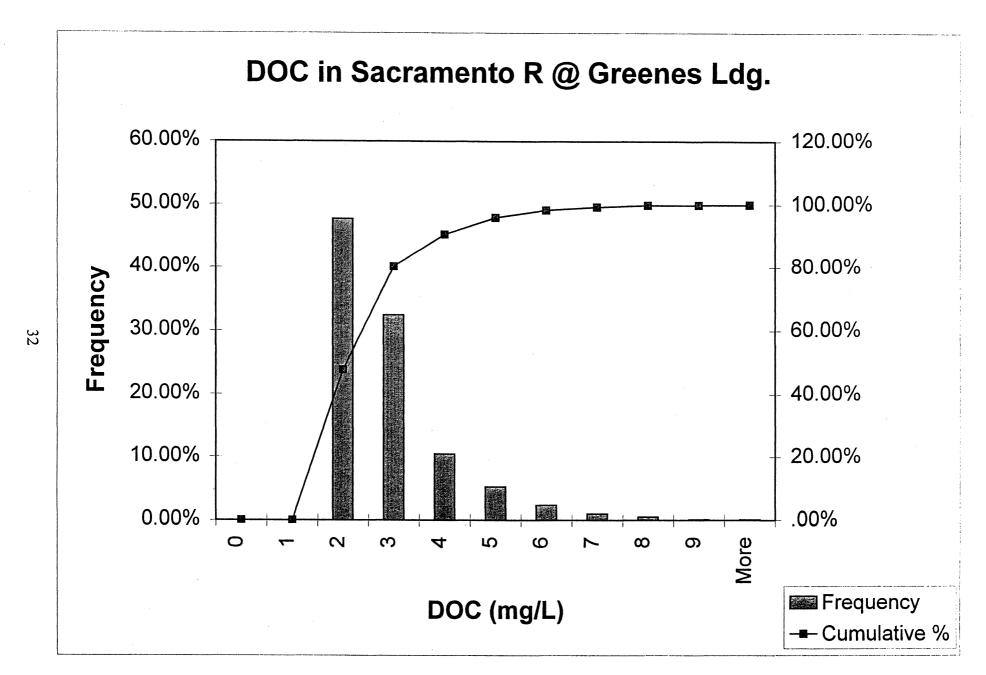
DOC in Sacramento R @ Greenes Landing

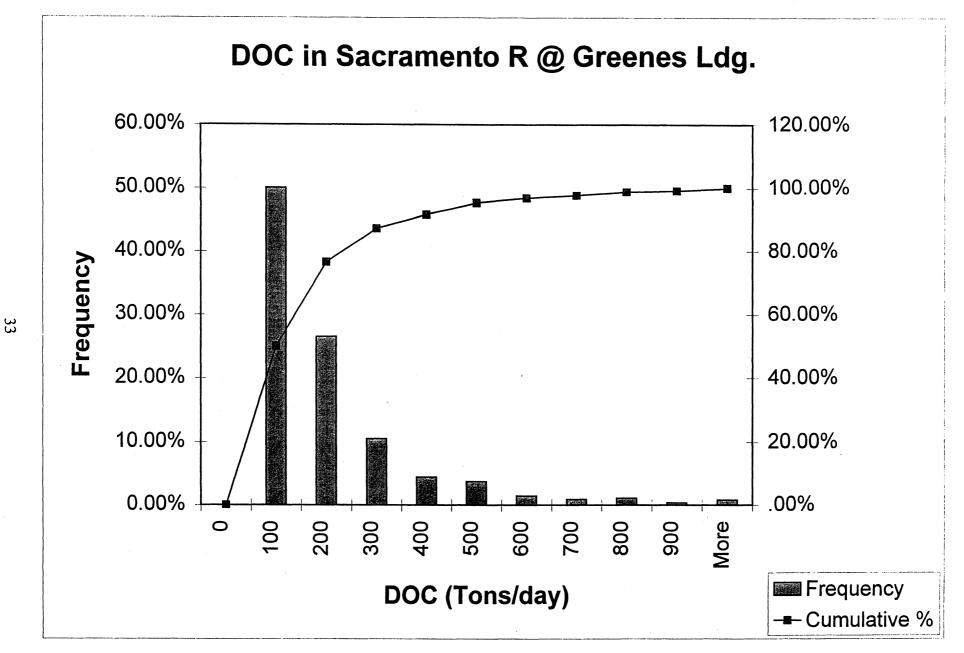


Month

DOC in Saramento R @ Greenes Landing







Mallard Island

This sampling location is located on the Sacramento River at Mallard Island, west of Antioch. Water quality at this location is heavily influenced by the Bay estuary and Pacific Ocean and the strong tidal action that occurs there. Mass loadings are not computed for this station because the strong tidal influence at this location can bring material into the Delta system as well as remove mass from the Delta. It is not unusual for 200,000 cfs flows to occur in both directions in the Mallard Island area as the tide flows in and out. Net Delta Outflow is generally only a small percentage of this tidal volume.

Figure 2-15 shows historic DOC concentrations and loads at Mallard Island. Trends of change are not evident; however, high variation in loading is experienced. Figure 2-16 indicates that DOC concentrations at this location are highest in March of dry years, with lows coming during the late fall of all years. November of wet years is associated with lowest concentrations.

Figure 2-17 indicates that about 80% of DOC concentrations found at Mallard Island fall within the 1 to 4 mg/L range.

San Joaquin River

The San Joaquin River is the second largest sources of fresh water inflow to the Delta, after the Sacramento River.

The monitoring station is located on the San Joaquin River near the small settlement of Vernalis, south of Stockton. The river at this location experiences only minimal tidal influence and flow generally does not reverse as a result of tidal action. Water quality and flow data have been collected from this location for many years.

Figure 2-18 shows the historical DOC record at the Vernalis station. No discernable trend of change is shown for DOC concentration, but loading during the period 1986 through 1994 tends to be lower than is the case for the period 1997 to recent. The difference is probably attributable to the fact that the earlier period was characterized by very dry conditions, and the latter by unusually wet conditions.

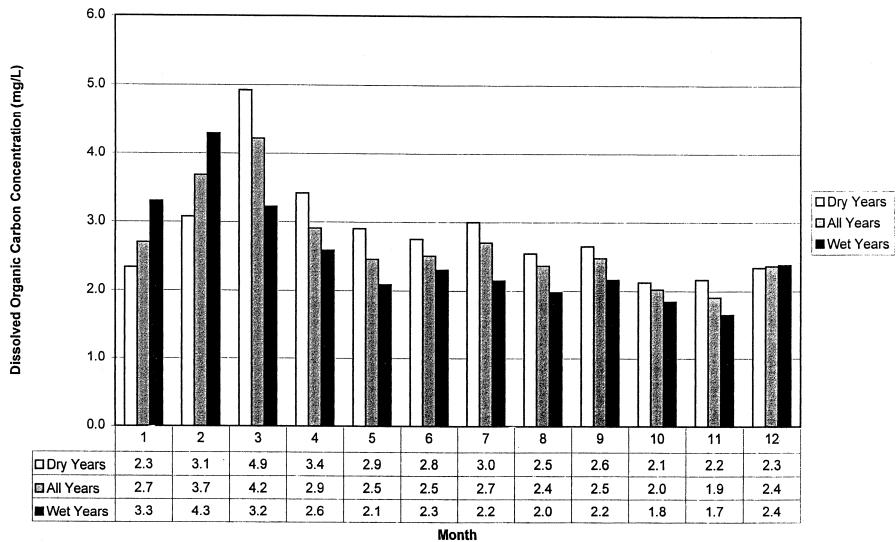
Figure 2-19 shows monthly mean DOC concentrations, along with the range encompassed within one standard deviation above and below the mean. February tends to be highest, while May tends to be lowest in DOC, on average. Figure 2-20 shows monthly DOC mass loads, and the range of one standard above and below the mean. As is true for concentrations, mass loads tend to be highest in Februaries. Mass loads tend to be lower in the late summer and fall months when river flows are lower.

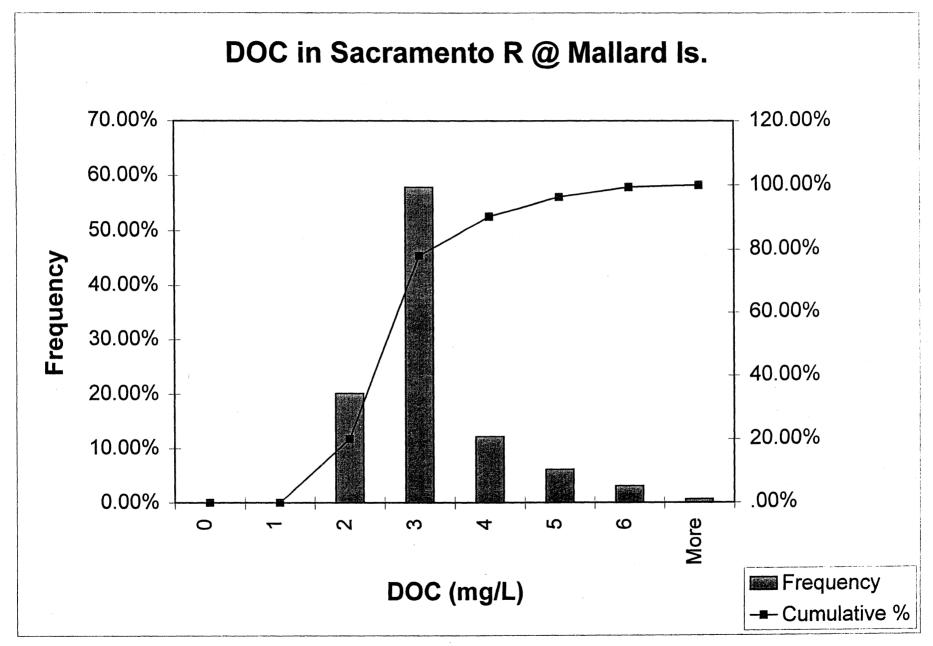
Figure 2-21, a display of average monthly conditions in different hydrologic conditions, shows wet months of dry years as being associated with highest DOC concentrations, while May of wet years is associated with lowest concentrations. Reservoir releases could account for the low DOC concentrations observed in that month of wet years.

80/1/1/ SOLVE . 80/1/5 10/1/1/1 10/1/E 56/1/6 COLLA Collins COLLA 56/1/6 16/1/ 16/11/5 06/1/5 ဖ 0 12 9 ω 4 Dissolved Organic Carbon (mg/L)

DOC in Sacramento R @ Mallard Is

DOC in Sacramento R @ Mallard Is



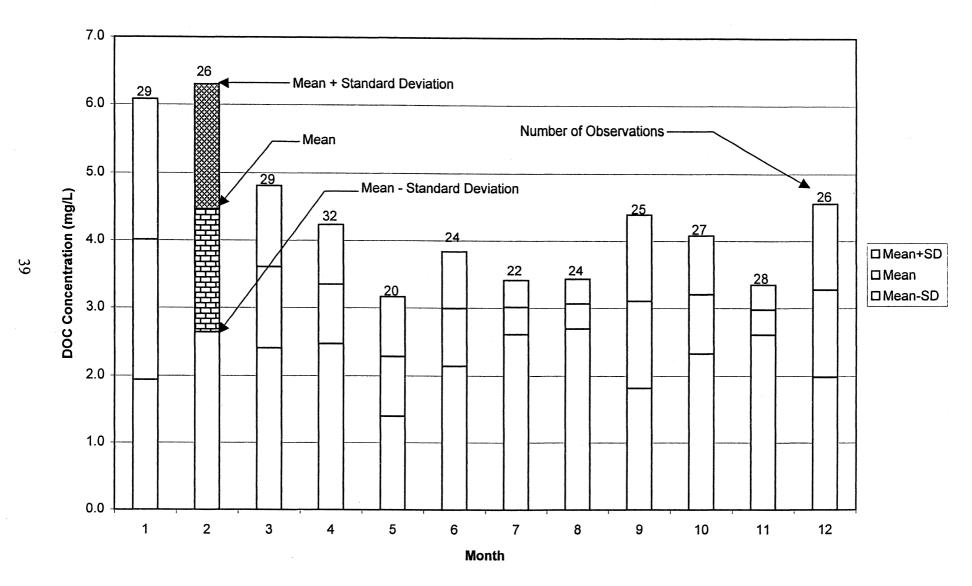


-Mass Load (Tons/Day) Concentration (mg/L) 66/1/9 86/1/2/ OCK 1/9 10/1/21 tolly Sold I Col OCK 1/9 SOLVE SOLVIO *6/1/6/ *OLI/O 60/1/2/ COKING COLUNCI COLLIS le/le/ 16/1/9 06/XX21 06/1/9 68/1/2/ 60/1/9 88/1/2/ 80/1/9 tollic. 101 10 NO 100 9 DOC

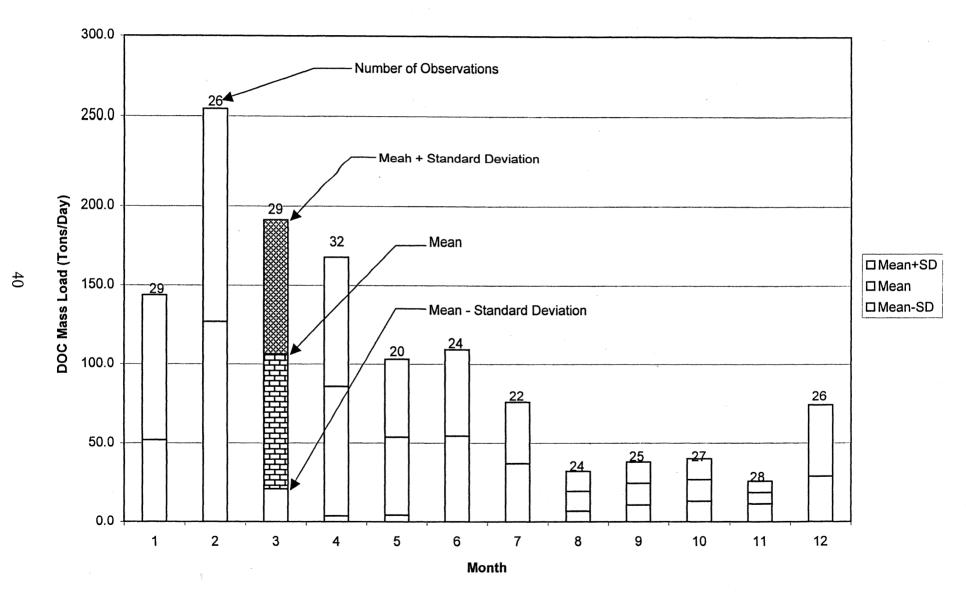
Dissolved Organic Carbon in San Joaquin River nr. Vernalis

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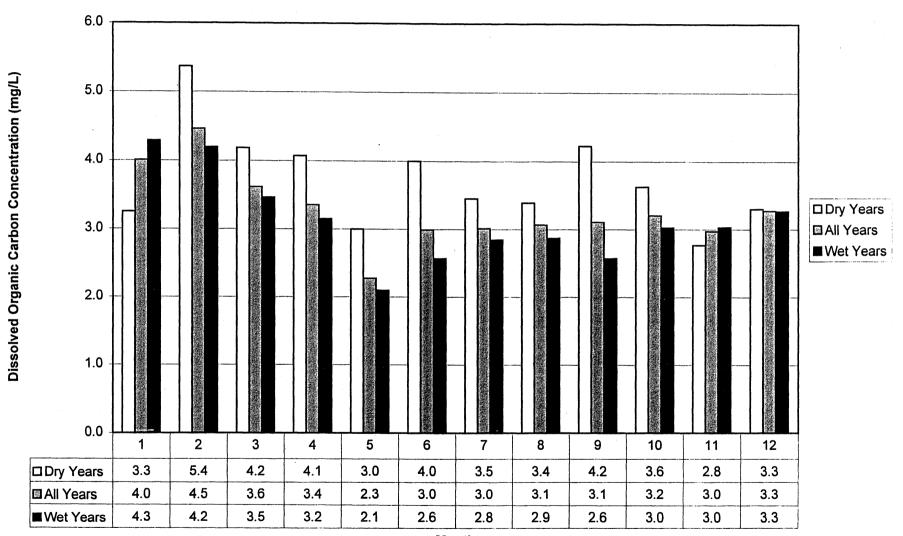
Dissolved Organic Carbon in S.J.R nr. Vernalis



Dissolved Organic Carbon in S.J.R. nr. Vernalis



DOC in S.J.R. nr. Vernalis



Month

Figure 2-22 demonstrates that wet months of wet years are associated with the highest loadings, with dry months contributing to only a minor degree. Frequency distributions shown in Figures 2-23 and 2-24 for concentrations and loadings, respectively, indicate most observations fall in the 3-5 mg/L range of concentrations, and in the 5 to 75 Tons/day range of loadings.

American River

The American River is the third largest stream inflow to the Delta, after the Sacramento and San Joaquin Rivers.

Figure 2-25 depicts historic DOC concentrations in the American River, measured at the intake to the Sacramento water treatment plant, located near the Howe Avenue bridge. The period of record extends from 1989 through recent. The period from 1989 through 1994 tends to be characterized by somewhat lower DOC concentrations and somewhat higher loads, compared to the period after 1994. This is probably a reflection of the fact that the earlier period was abnormally dry, while the latter period was unusually wet.

Figure 2-26 shows monthly average distributions of DOC under different hydrologic conditions. As was depicted in the historic figure, dry periods are associated with higher DOC concentrations, whereas, referring to Figure 2-27, the loading chart, the opposite pattern is the case with loadings: Wet months of wet years produce the highest loads. The distributions of DOC concentrations and loads, depicted in Figure 2-28, and Figure 2-29, respectively, indicate that, for this location, most concentrations fall in the 1.3 mg/L to 3.0 mg/L range, whereas most loads fall in the 10 to 30 tons/day range.

Discharges

The Delta is subject to discharges of treated waste water from the Sacramento Regional County Sanitation District facility on the Sacramento River at Freeport, from the Stockton waste water treatment facility in Stockton, from storm water drainage from Sacramento and Stockton, and from drainage from Delta islands. DOC data are presently available for the Sacramento storm water system and Delta islands, and are discussed below.

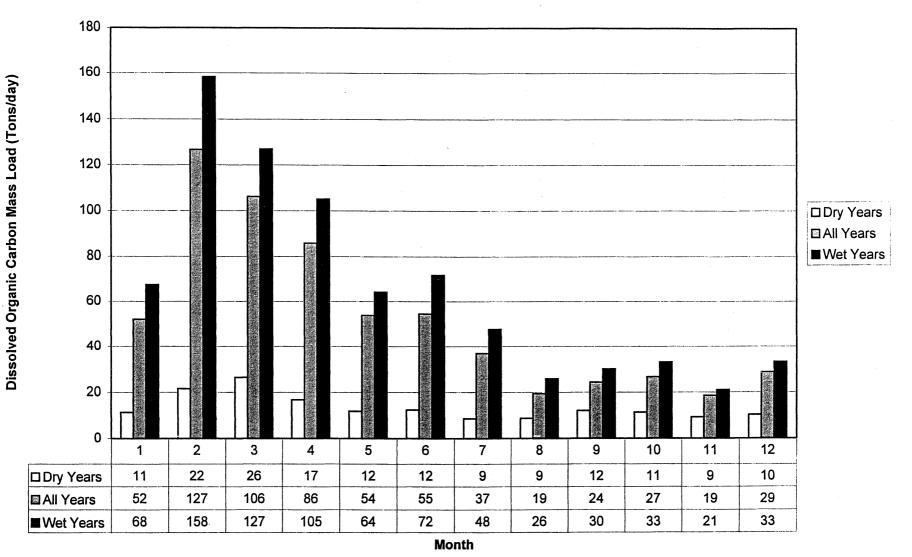
City of Sacramento Storm Water

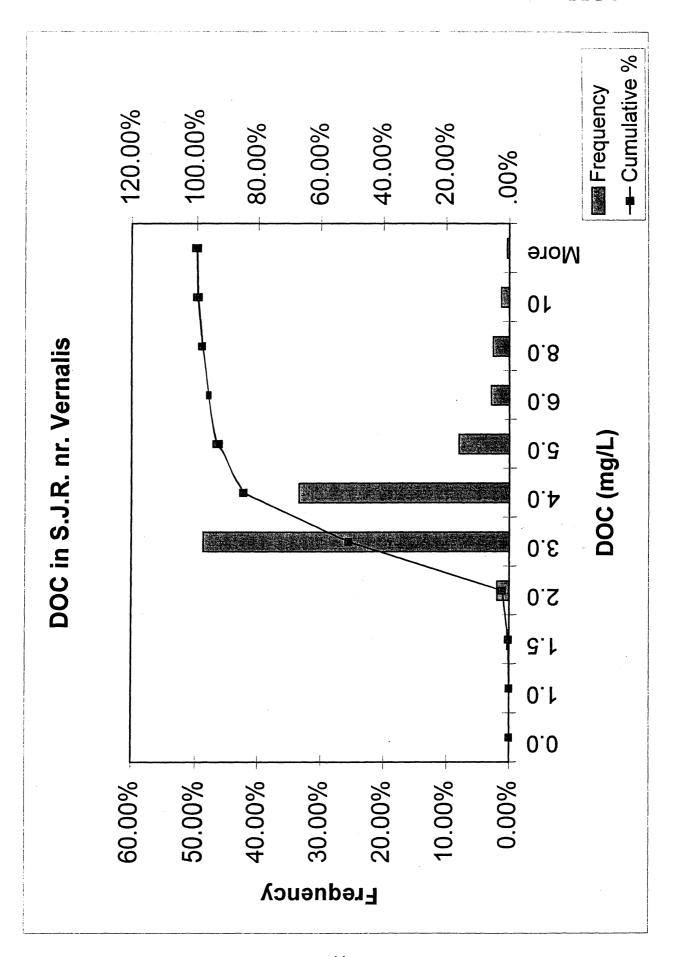
Based on 37 storm drain samples collected from three Sacramento locations over the period December 1995 through September 1998, the average DOC in Sacramento storm drain samples was 10.0 mg/L, with a standard deviation of 8.1 mg/L.

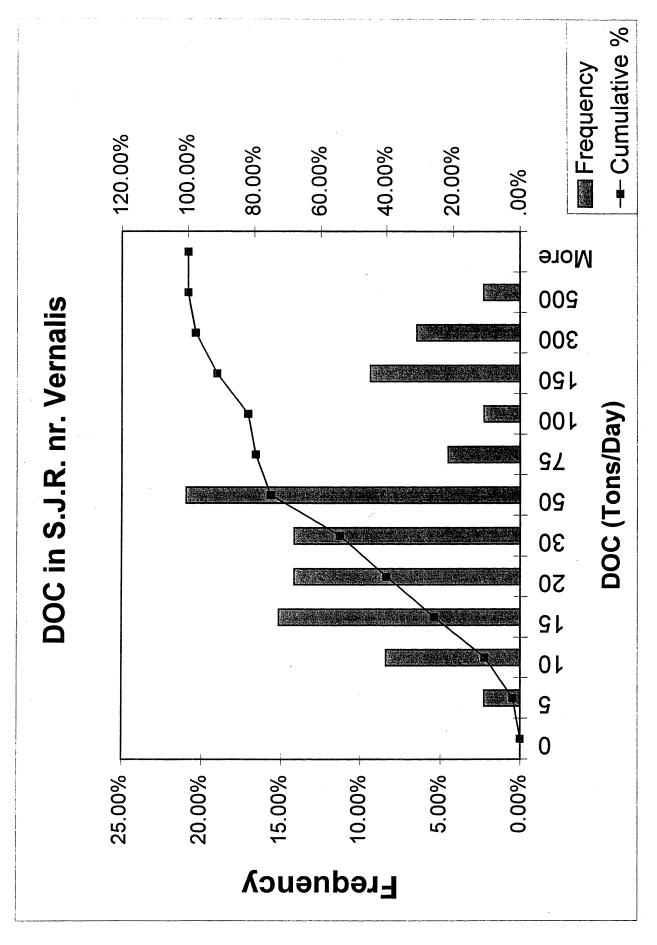
Delta Island Drainage

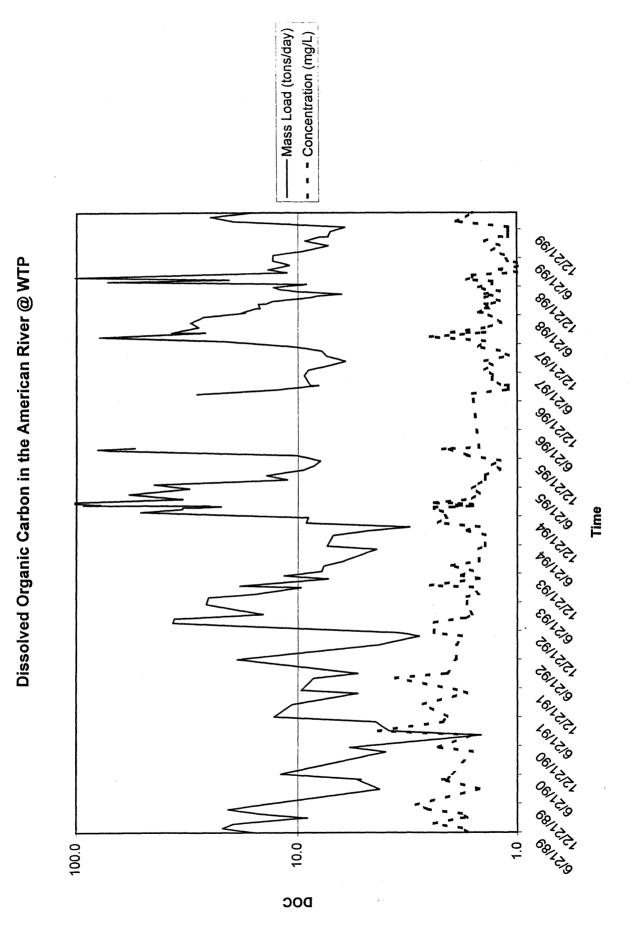
Some 260 drain systems discharge to the waters of the Delta from the islands there. In general, Delta islands are below sea level, which causes seepage into the islands to occur from adjoining channels. This seepage must be collected and returned to the channels in order to keep the islands dry. Most of the islands are presently used for agricultural production, which involves siphoning water from adjacent channels onto the islands for crop irrigation, then collecting and returning the residual water to the channels by use of

DOC in S.J.R. nr. Vernalis

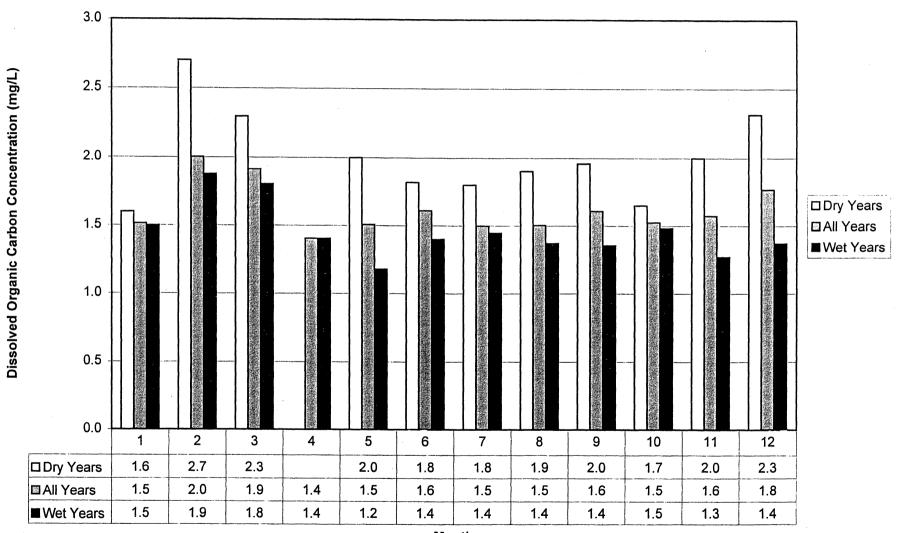




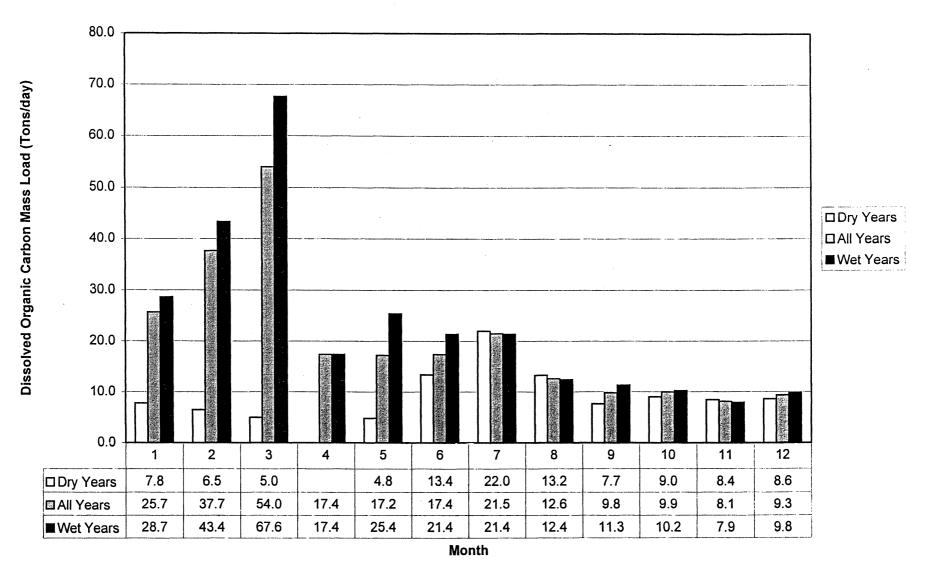


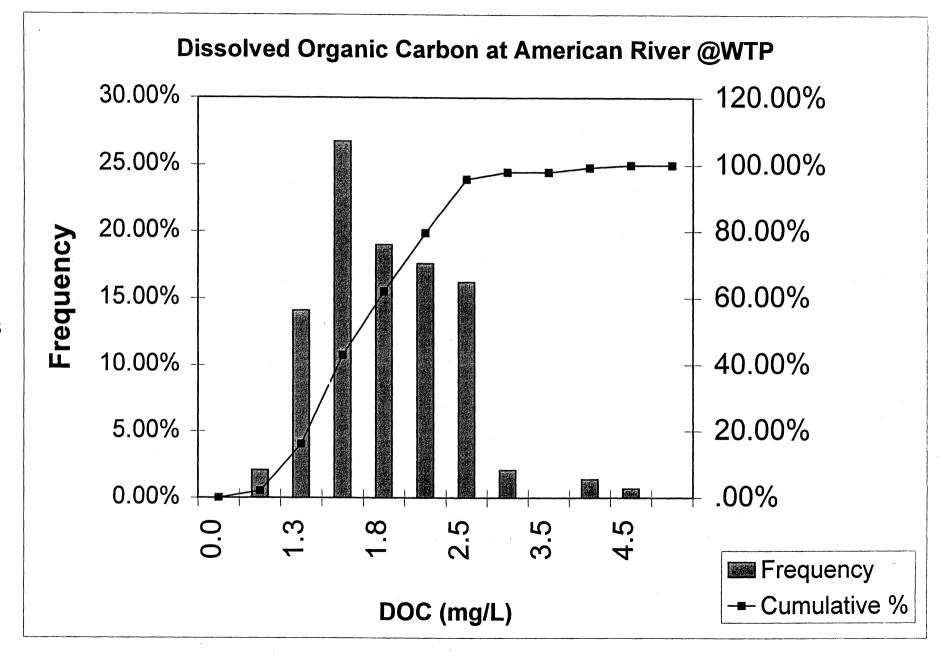


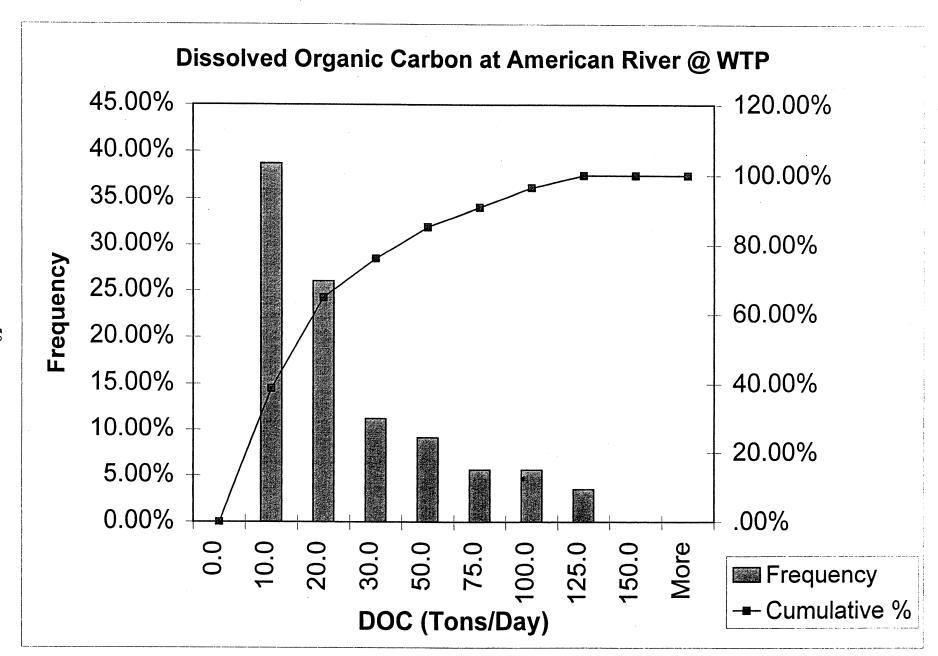
DOC in American R @ WTP



Month







pumps. Islands in the central area of the Delta are generally characterized by peat soils, having high organic content. When water flows over and through these soils, organic carbon dissolves and is carried by the drainage system into Delta channels which feed the drinking water systems using Delta waters. The Department of Water Resources estimated that, during summer irrigation months, island drainage contributes 40 % to 45% of the carbon that reacts in water supplies taken from the Delta to form DBPs. The Department also estimated that island drainage from the winter months when soil leaching occurs contributes 38% to 52% of the DBP-forming carbon. 1/

Figure 2-30 shows average monthly DOC concentrations in island drainage under different hydrologic conditions. Peaks occur in the fall when irrigation drainage occurs and during the winter months when soil leaching is done. Please note that the summer months of dry years are associated with higher concentrations, whereas winter months of wet years are associated with highest concentrations. These data appear to reinforce the concept that the irrigation season and leaching seasons represent distinctly different regimes. Monthly summaries of loadings shown in Figure 2-31 demonstrate that wet months in all years account for the majority of loadings.

Diversions

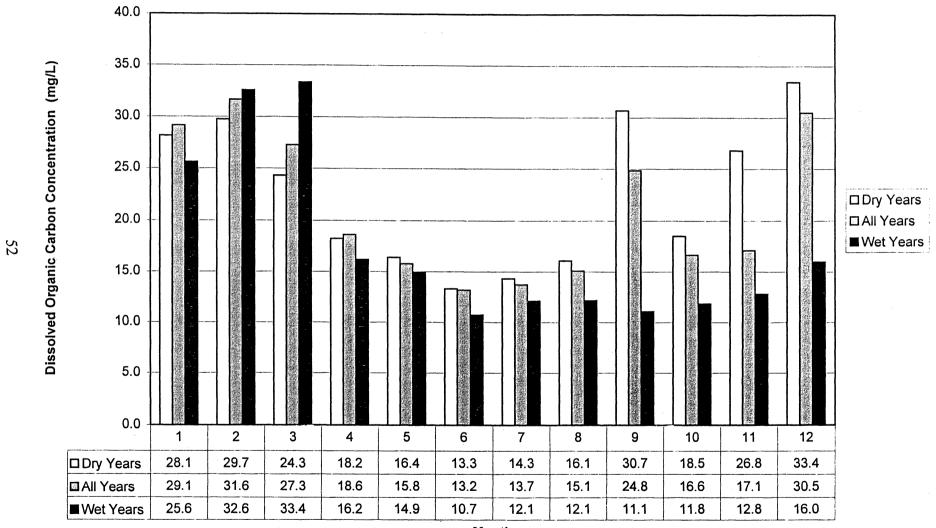
The primary diverters of Delta waters for drinking water use are the State Water Project that diverts from Barker Slough in the North Delta, and from Old River through Clifton Court and the H.O. Banks Pumping Plant in the South Delta. A short distance downstream from the Banks pumping plant in the California Aqueduct, the South Bay Pumping Plant takes water into the South Bay Aqueduct that serves the South Bay area. Contra Costa Water District diverts water from three Delta locations: Mallard Slough in the western Delta (used only during high outflow periods when salinity is adequately repelled); from Old River through Rock Slough by its Pumping Plant #1; and, from Old River near the Highway 4 crossing, in the southern Delta between Rock Slough and Clifton Court.

The Central Valley Project diverts water into the Delta Mendota Canal through its Tracy Pumping Plant in the south Delta, and supplies drinking water to the City of Tracy. Near Los Banos, the federal Central Valley Project Delta Mendota Canal and State Water Project California Aqueduct are connected by O'Neill Forebay, which causes water from both sources to intermingle, from which point it is served to the San Luis Obispo and Santa Barbara areas, and to the greater Los Angeles area south to San Diego. Water is also taken from San Luis Reservoir (connected to O'Neill Forebay) for use as drinking water supply by Santa Clara Valley Water District. That District takes water both from San Luis Reservoir and the terminous of the South Bay Aqueduct.

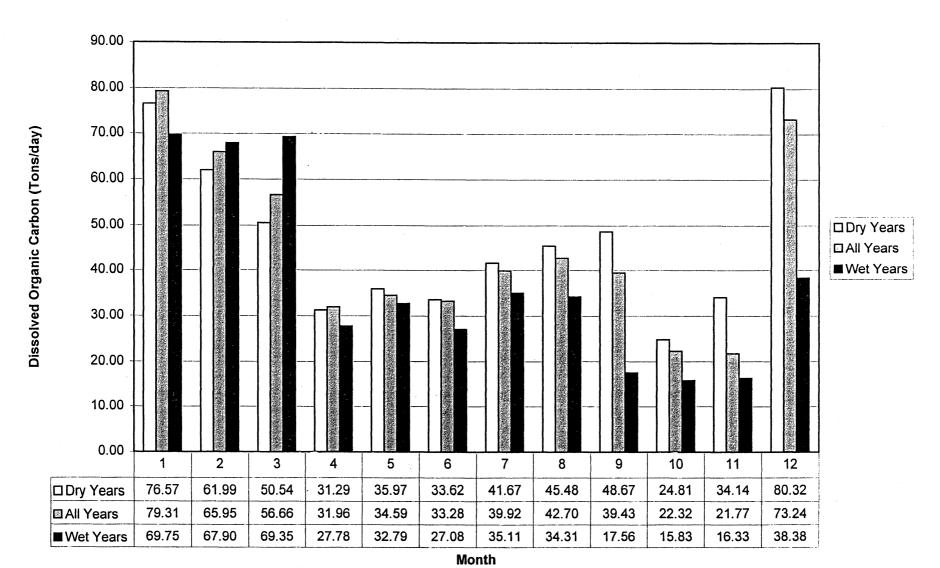
North Bay Aqueduct, State Water Project

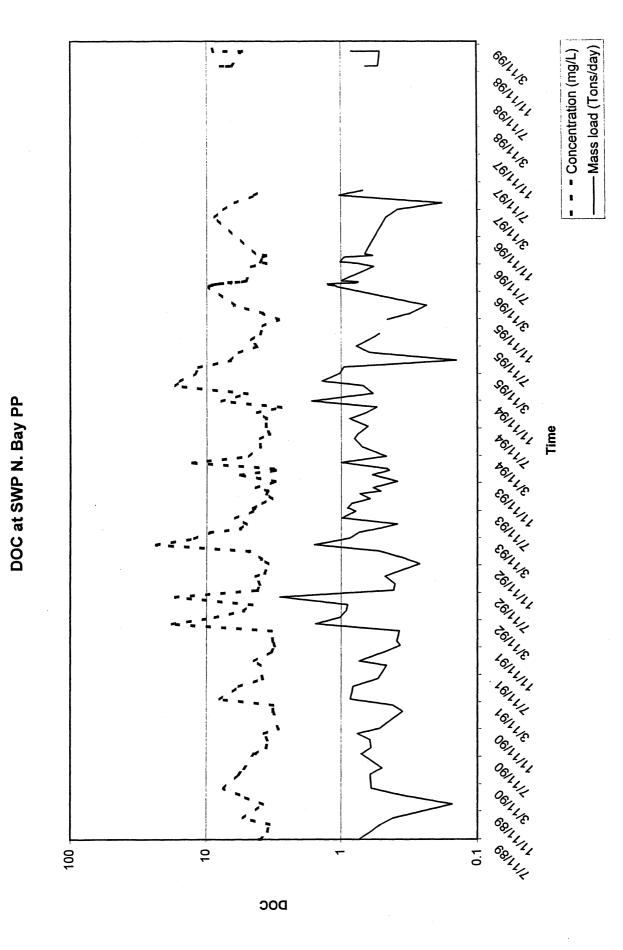
Figure 2-32 depicts the historic record of DOC at the North Bay Pumping Plant, the intake to the North Bay Aqueduct of the State Water Project. No obvious trends of change are apparent. Figure 2-33, representing monthly DOC concentrations under different hydrologic conditions, depicts wet months of wet years contributing highest DOC concentrations, with dry months of all years having less than half the concentrations

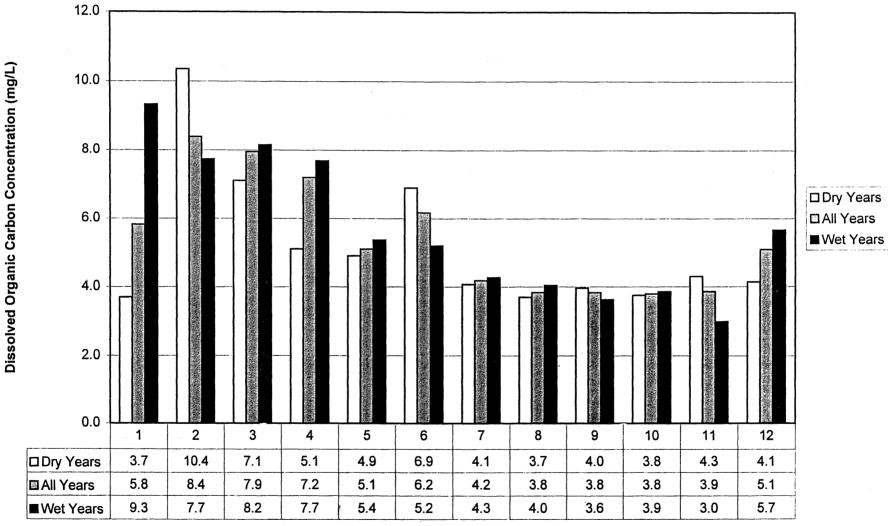
DOC in Delta Island Drainage











Month

as wet months in wet years. Loadings, depicted in Figure 2-34, are not typical of observations at other locations. Dry months of dry years contribute the highest loads, the opposite of the case in the Sacramento River at Greenes Landing. This may be an indication of the influence of the local watershed. Figure 2-35 and Figure 2-36 show that concentrations are most often in the 4-5 mg/L range, and loads are most frequently in the 0.75 to 1.0 tons per day range. (Please note that loading is a function of pumping activity and does not, therefore, represent a natural condition.)

California Aqueduct, State Water Project

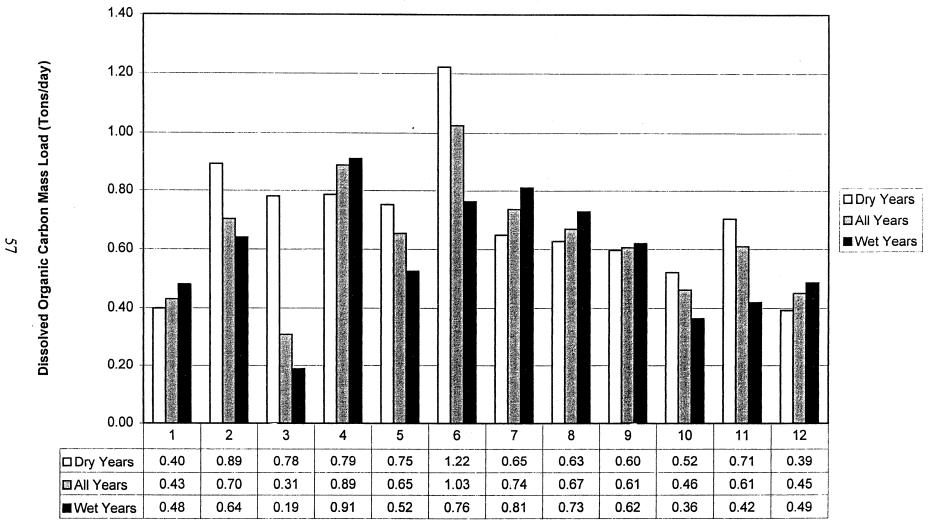
Figure 2-37 depicts historic DOC concentrations and loads taken into the California Aqueduct through H.O. Banks Pumping Plant. No clear trends of change with time are evident. Loads are dependent on plant operations and are useful only as an indication of the mass of material being sent to drinking water purveyors, not as a representation of a natural condition. Figure 2-38, showing average monthly DOC concentrations over different hydrologic conditions indicate that wet months are associated with higher concentrations. This is a significant issue because, as a general matter, water is most available for diversion during wet, high flow conditions when DOC concentrations can be twice as high as at other times of year. Observation of Figure 2-39, the loading chart for this location, demonstrates that loadings are highest during the wet months. Interestingly, loadings are highest during January of wet years, whereas March of wet years are characterized by much lower loadings than during March of dry years. This phenomenon may be due to greater reservoir releases during the spring period of wet years. Figure 2-40 shows that most DOC is most often observed in concentrations of the 3 to 5 mg/L range; Figure 2-41 indicates about 90% of DOC loads fall in the 25-75 Tons/day range.

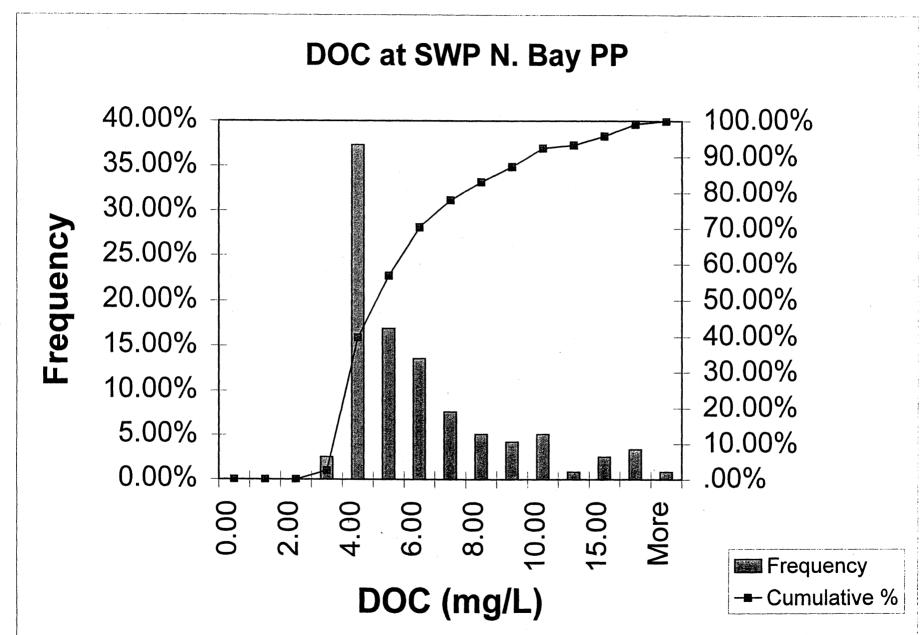
Contra Costa Water District Pumping Plant #1

Sparse data have been collected at the CCWD's Mallard Slough intake through the Department of Water Resources' Municipal Water Quality Investigations Program. This location is not frequently operated due to typical adverse water quality conditions at that location. Data are presently being collected at the CCWD intake location on Old River near the Highway 4 crossing. However, this is a new intake facility constructed as part of the Los Vaqueros Reservoir complex, and the period of record is presently too short to be used for depicting any but most recent conditions. Data have been collected at the Pumping Plant #1 station for some years; due to the lack of data from the other intake locations, only data from the latter location are used in this analysis to represent the quality of water received by Contra Costa Water District. When the Mallard Slough facility is operated it is generally during wet conditions when water quality is generally good, typical of the upstream Sacramento River. The quality of water taken through the Highway 4 intake is generally better than is found at Pumping Plant #1, and generally somewhat lesser in quality than is observed at the State Water Project intake further south.

Figure 2-42 depicts historical DOC observations at Pumping Plant #1. Significant swings in DOC loading are observed, but the reader must remember that loadings are dependent on project operations, and do not represent a natural condition. Still, there is a

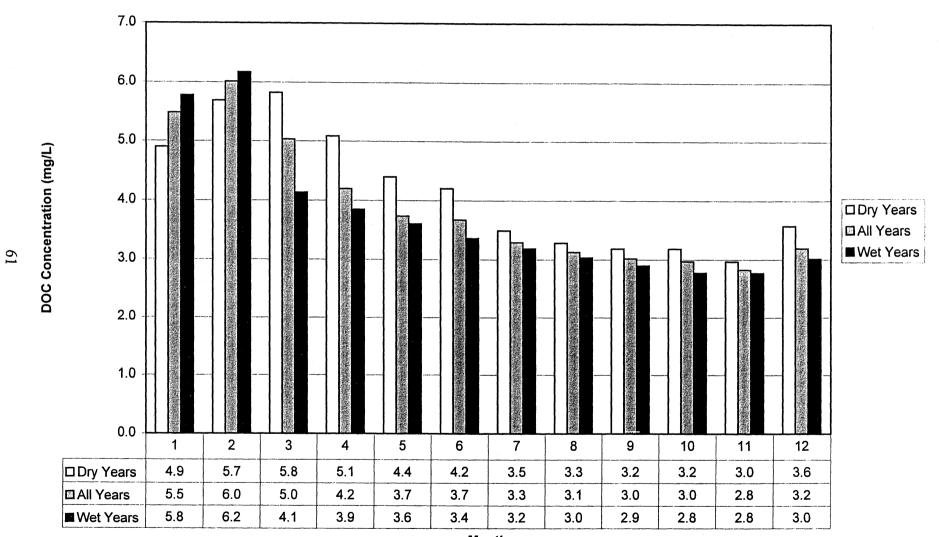
DOC at SWP North Bay PP

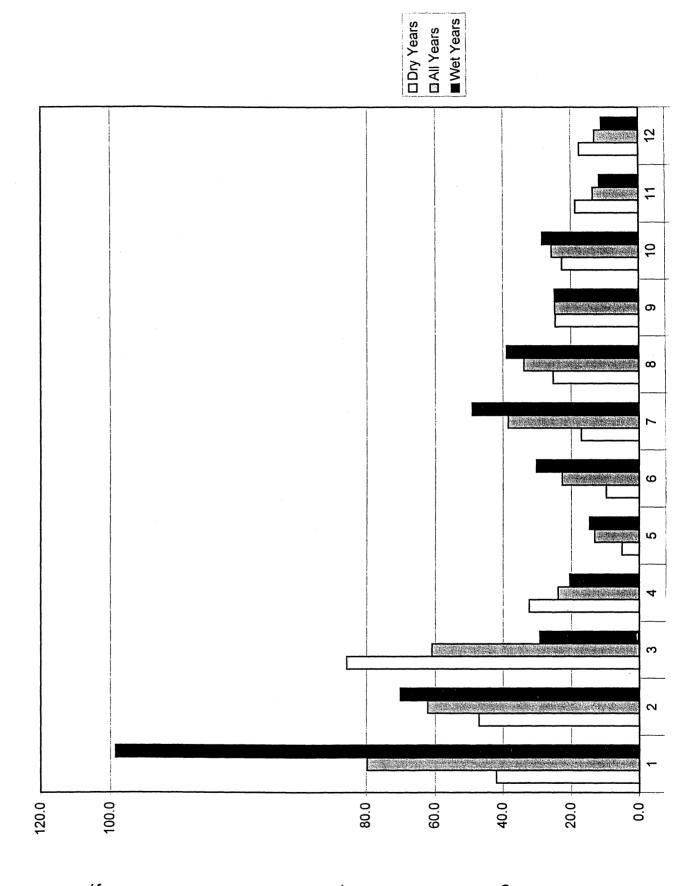




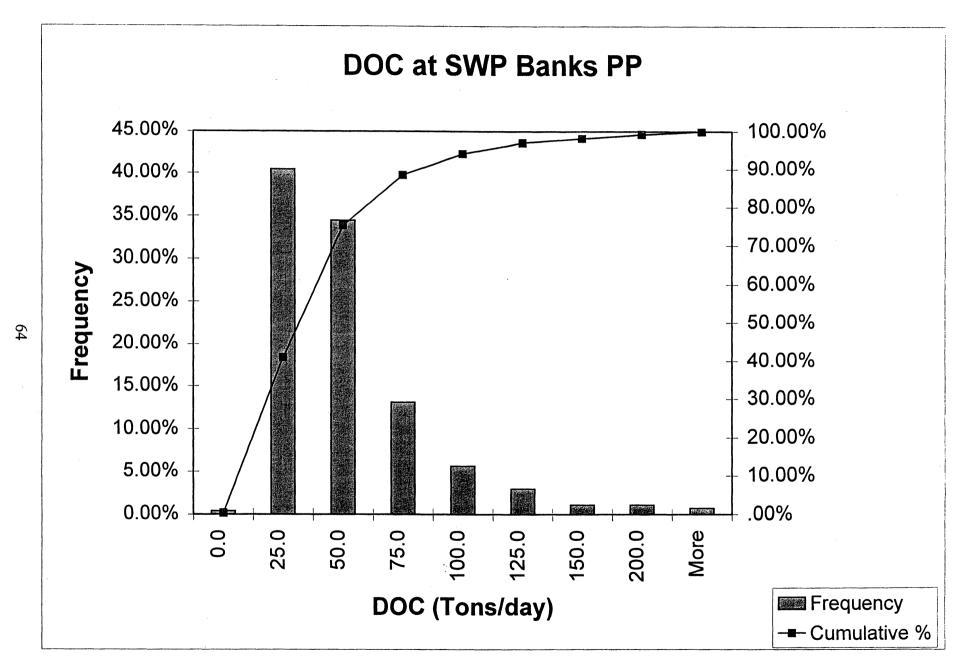
·Mass Load (Tons/day)
Concentration (mg/L)

DOC at SWP Banks PP





Dissolved Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Load Organic Carbon Mass Load Organic Carbon Mass Load (To The Lo



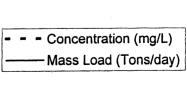
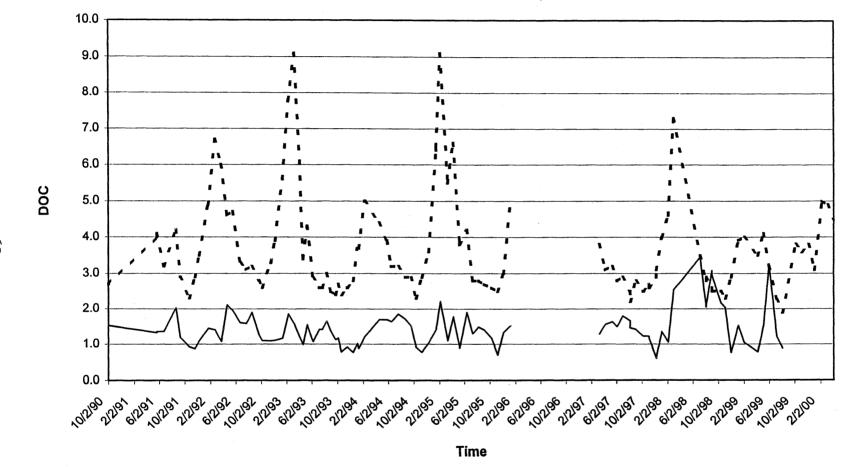


FIGURE 2-42



correspondence of higher concentrations and higher loadings. No long term trends of change are apparent. Figure 2-43 shows that wet months of all years are associated with greater DOC concentrations, but that, according to Figure 2-44, greater loadings tend to be experienced in drier months, especially of wet years. Figure 2-45 indicates most concentrations fall in the 3 to 6 mg/L range of concentrations, while Figure 2-46 shows most loadings falling in the 1 to 2.5 Tons/day range. The much lower loadings than are experienced at Banks Pumping Plant are a reflection of the smaller size of the CCWD system, not of better quality water.

Delta Mendota Canal Intake at Tracy Pumping Plant

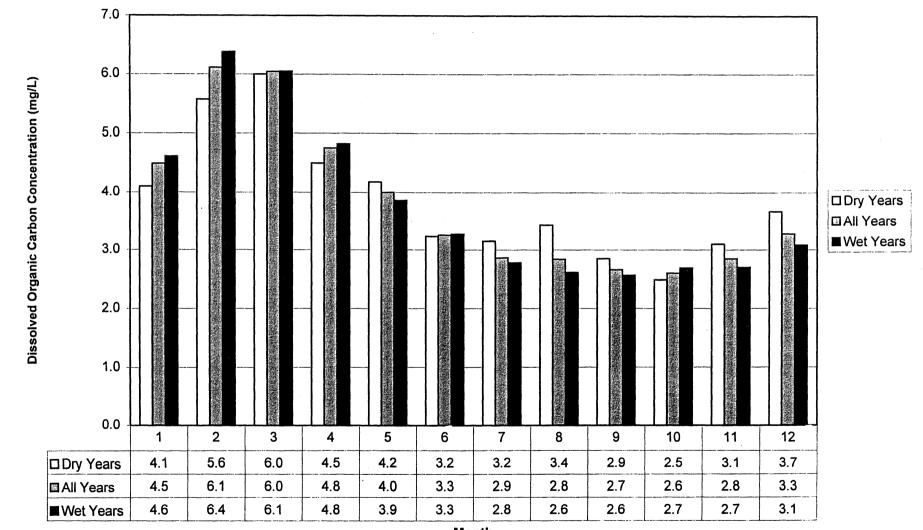
Figure 2-47 shows historic DOC conditions at the DMC intake. No long terms trends of change are evident. Figure 2-48 shows that wet months are characterized by elevated DOC concentrations, with wet months of dry years being highest and dry months of wet years being lowest. Greater reservoir releases during dry months of wet years may account in part for this observation. Another possibility is that, because dry years are usually associated with low flows in Delta channels and greater light penetration, algal growths during such conditions may contribute to higher DOC during the warm months of dry years. Figure 2-49 shows that wet months dominate in loadings, with March of dry years being highest. January of wet months is associated 1 with higher loadings than January of dry months; whereas the opposite pattern appears in March. This is an indication of different processes at work, probably at least in part related to operation of the facility. Figure 2-50 shows that about 80% of observed DOC concentrations fall in the range of 3 to 6 mg/L, and Figure 2-51 shows a similar percentage of loads falling in he 10 to 50 Tons/day range. Concentrations in the range of 4 to 5 mg/L were most often observed, and most frequently observed were loads in the 30 to 40 Tons/day range.

Total Organic Carbon

Total Organic Carbon is measured on unfiltered water samples, and represents dissolved, as well as particulate carbon. Prior to promulgation of Stage I of the federal Disinfectants and Disinfection Byproducts Rule in 1998, most of the attention of drinking water purveyors was on DOC as a predictor of disinfection byproduct formation capacity in drinking water supplies. As a consequence, most of the available data was for DOC. However, the Stage I D-DBP Rule required source waters to be monitored for TOC and, where concentrations regularly exceed 2.0 mg/L, to investigate means of optimizing treatment for TOC removal. The new rule raised interest in TOC monitoring with the result that more TOC samples have been collected. To date, the database for DOC is considerably larger than for TOC, and comparisons between the two forms should be done in the realization that the data sets are unequal.

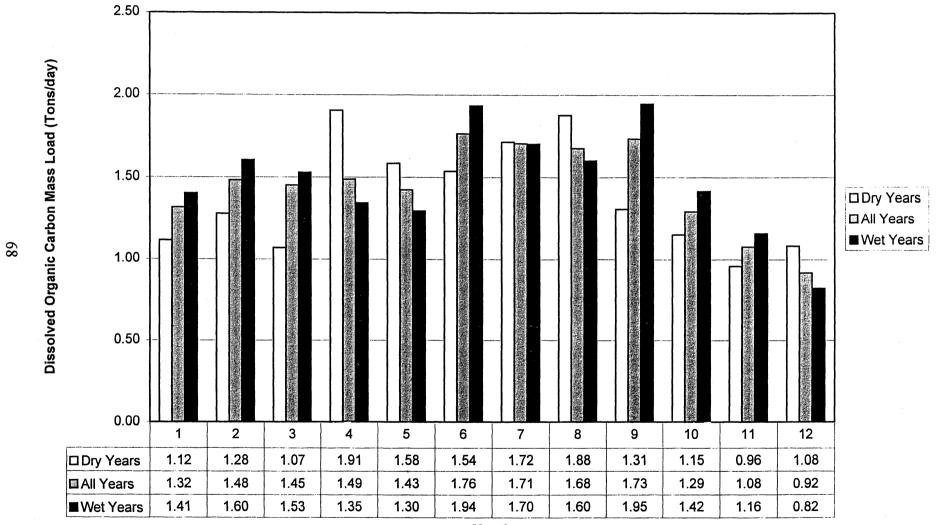
Figure 3-1 depicts overall TOC mass loads to the Delta. The Sacramento River Comprises two-thirds of the total loading. The San Joaquin River and American River contribute 11 percent and 8 percent, respectively. Based on very limited data, the Sacramento Regional County Sanitation District may contribute about 4 percent of the load, and based on more extensive information, drainage from Delta islands contributes up to 11 percent of the TOC load in Delta waters. The figures for the Sacramento Regional plant and island drains will prove to be overestimates of the actual net TOC

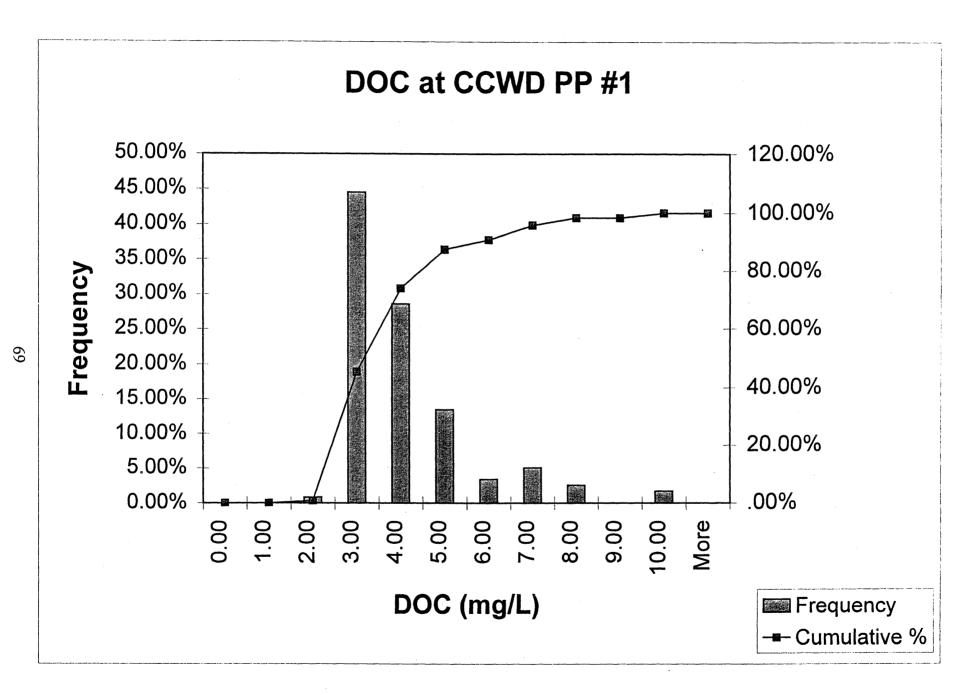
DOC at CCWD PP #1

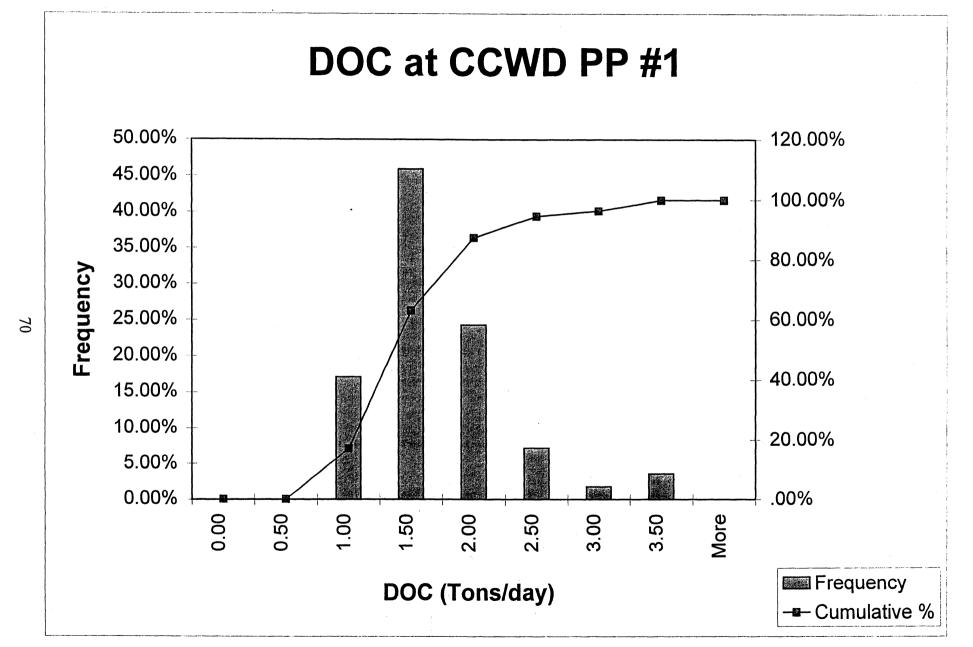


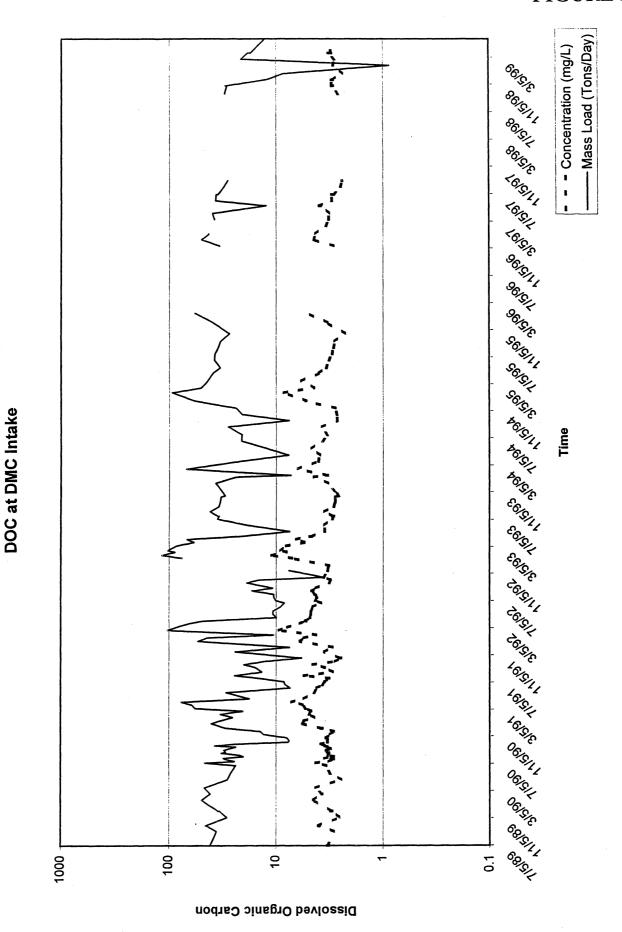
Month

DOC at CCWD PP #1

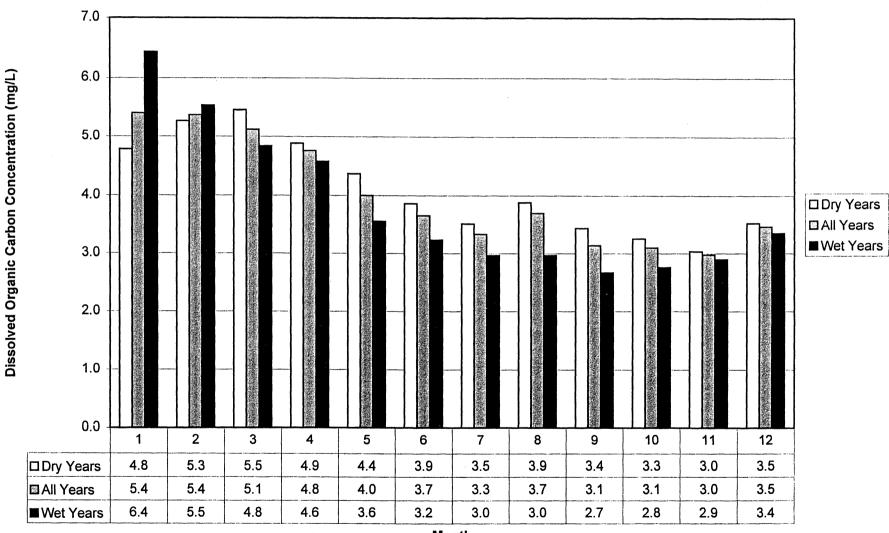












Month

70.0

60.0

■ Wet Years

64.6

52.6

45.8

38.3

15.7

31.0

Month

35.4

35.5

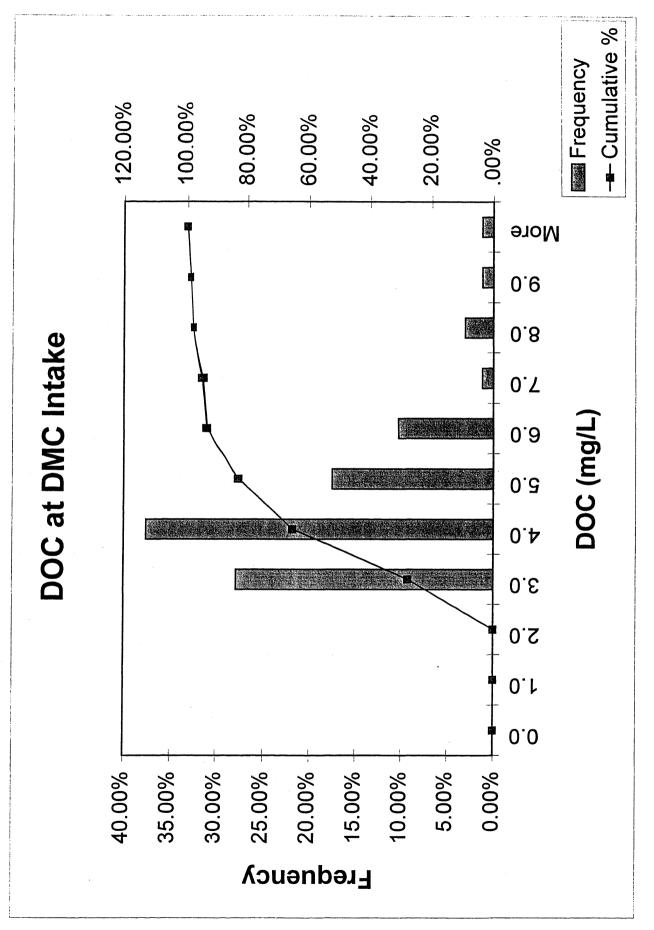
31.4

29.6

33.5

22.7

□ Dry Years □ All Years ■ Wet Years



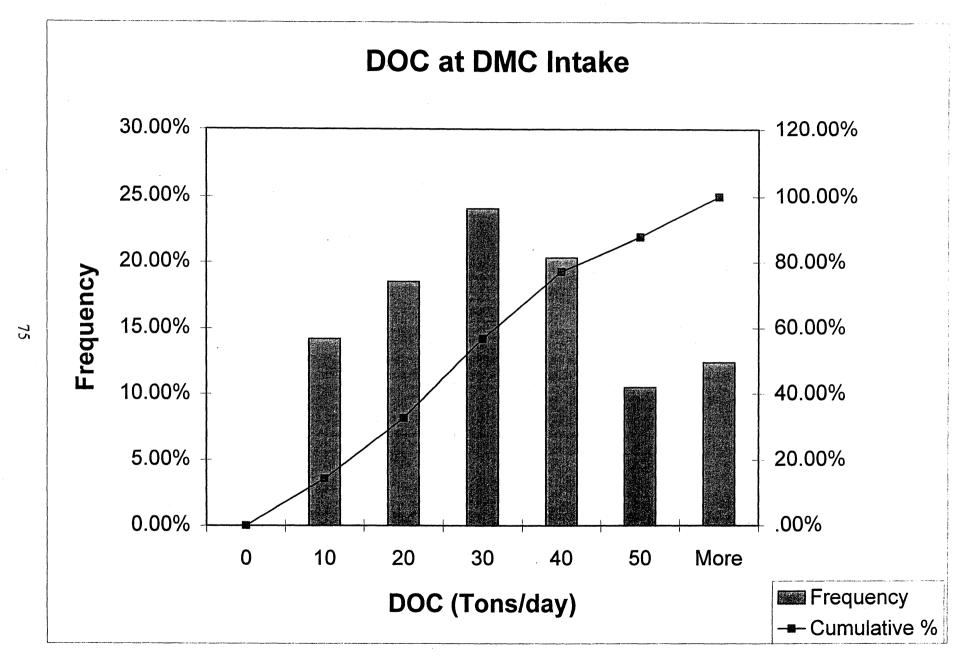
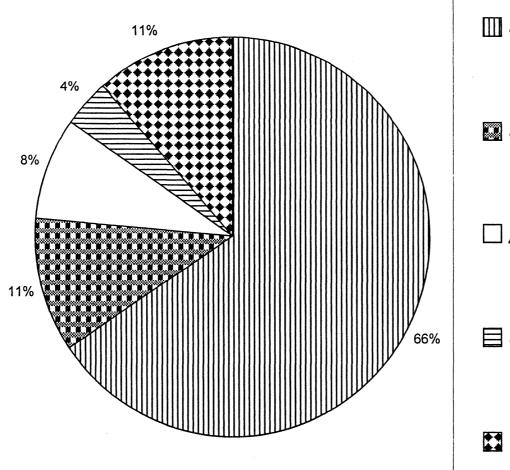


FIGURE 3-1

TOC Loadings to Sacramento-San Joaquin Delta



- Sacramento R.
- San Joaquin R.
- ☐ American R.
- **Sac. WWTP**
- Delta Islands

contribution, because water taken from the Sacramento River and Delta contains some TOC before additional loads are added through municipal and agricultural uses of the water.

Figure 3-2 presents an overall view of TOC concentrations and loads observed at various locations in the Delta area. Waters diverted for drinking water use from the south Delta are higher by one-third, as compared to the Sacramento River, and are similar to TOC in the San Joaquin River. Notably, the North Bay Aqueduct is characterized by TOC concentrations two and one-half times higher than are found in the Sacramento River. As was mentioned in the section on DOC, studies by the Department of Water Resources have indicated the local watershed is a major contributor. /2

Delta islands are important contributors, in an aggregate quantity similar to that contributed by the San Joaquin River. High TOC loads at Mallard Island, computed by use of Delta Net Outflow, shows large loads present in the western Delta, although these loads would affect fresh waters of the Delta only insofar as sea water intrusion occurs.

Delta Triburaries

TOC is discussed for the three streams that comprise the significant inflows to the Delta.

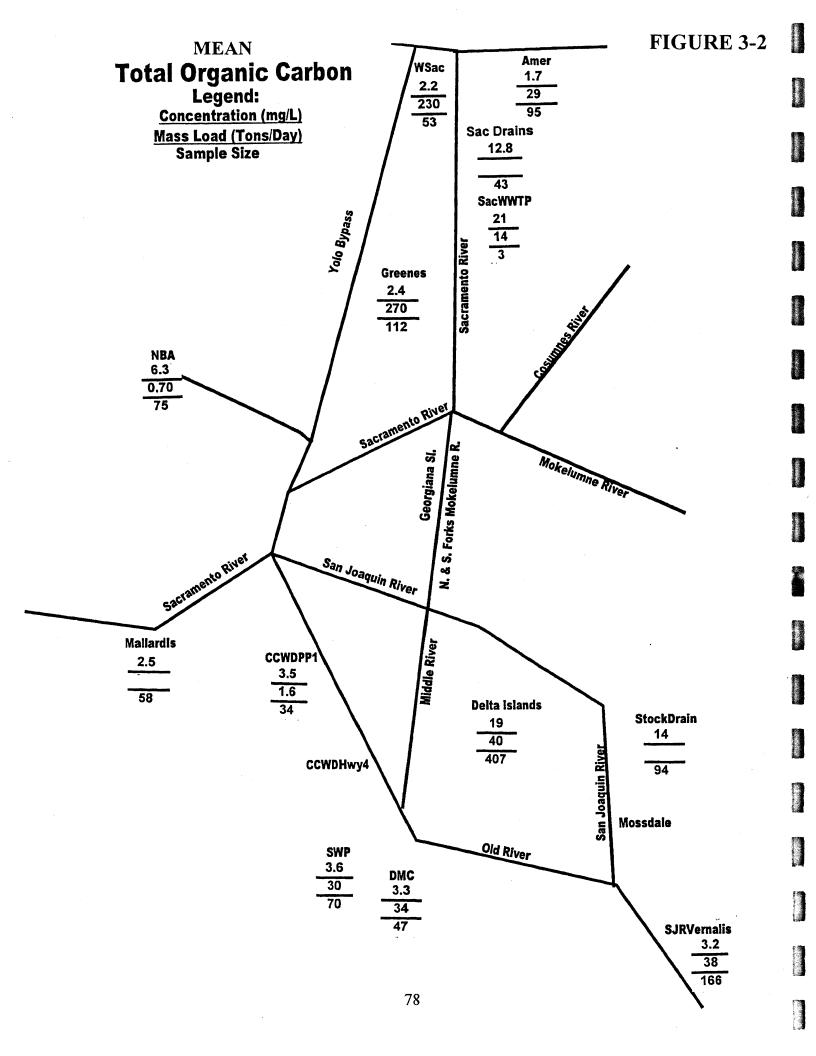
Sacramento River The Sacramento River is the largest fresh water inflow to the Delta, and generally has a dominant influence over Delta water quality.

Greenes Landing

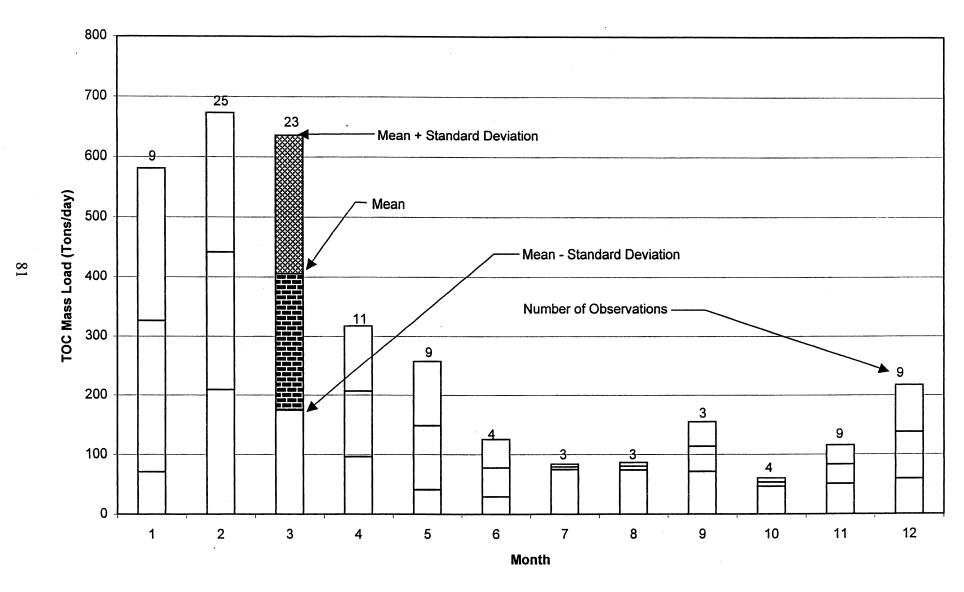
Figure 3-3 depicts historical TOC data for the monitoring location at Greenes Landing. No trends of change are apparent.

Figure 3-4 shows monthly mean TOC concentrations, along with the range encompassed within one standard deviation above and below the mean. Based on only three samples, September appears to be highest, though the small number of samples suggests this may be an artifact, rather than a reflection of actual conditions. Given that DOC maxima tend to occur under higher flow conditions, a conclusion that TOC is higher in September would probably be inaccurate. Spring and summer months appear to be associated with lower TOC concentrations. Figure 3-5 shows monthly TOC mass loads, and the range of one standard above and below the mean. Mass loads tend to be higher during the period January through March, when flows are typically higher. Mass loads tend to be lower in the summer and fall months when river flows are lower.

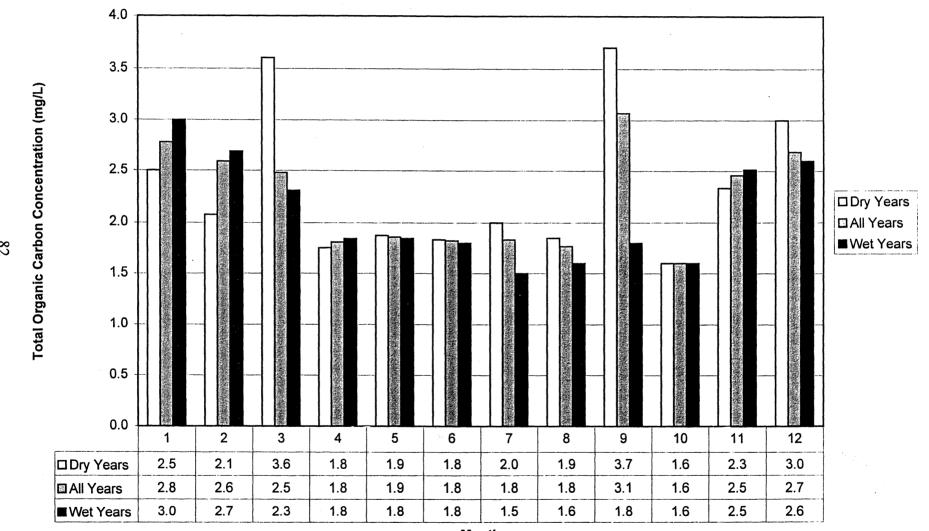
Figure 3-6 presents average monthly TOC concentrations during different hydrologic conditions. September of dry years appears to be associated with highest TOC concentrations. DOC data demonstrate a similar pattern. Note that TOC concentrations during the fall and winter months are typically in excess of the 2.0 mg/L limit that requires treatment studies to be performed by drinking water purveyors. Figure 3-7, which estimates TOC loadings, indicates that the winter months are very important, which will be due to the high flows experienced during that time of year. This is especially the case in wet years. The implication of high TOC concentrations and



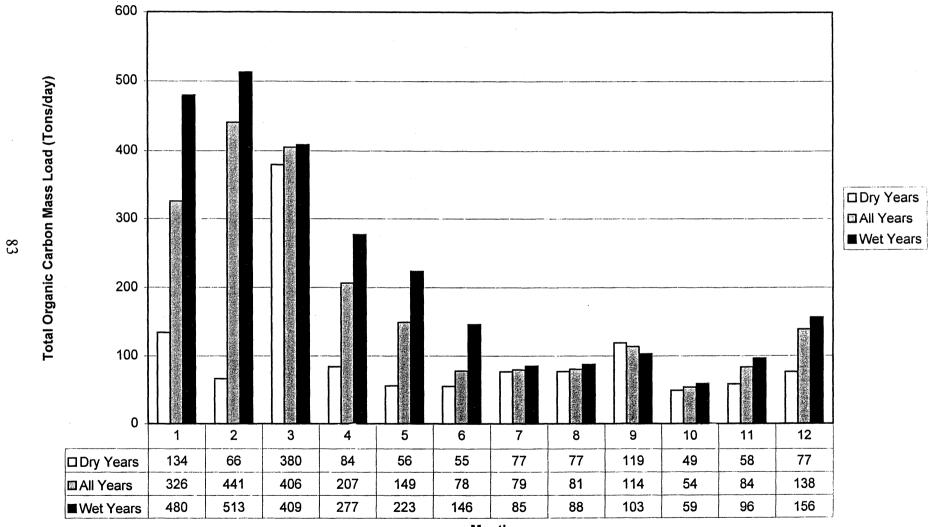
Total Organic Carbon in Sacramento R @ Greenes Ldg



TOC in Sacramento R @ Greenes Landing



TOC in Sacramento R @ Greenes Landing



loadings during the wet months is that drinking water agencies using the Delta are faced with maximum TOC at times when most water is available for diversion. Maximum diversions during the wet periods will tend to select for high TOC concentrations and loads in drinking water supplies taken from the Delta.

Figure 3-8 and Figure 3-9 demonstrate that most observed TOC concentrations fall in the range of 2 to 4 mg/L, and within a 100 to 600 Tons/day range, respectively.

Mallard Island

TOC data for this location in the western Delta are relatively sparse, but do reflect the condition observed at Greenes Landing; namely, high concentrations associated with wet months, particularly in wet years. (Please refer to Figure 3-10.)

San Joaquin River

The San Joaquin is second largest fresh water inflow to the Delta, after the Sacramento River.

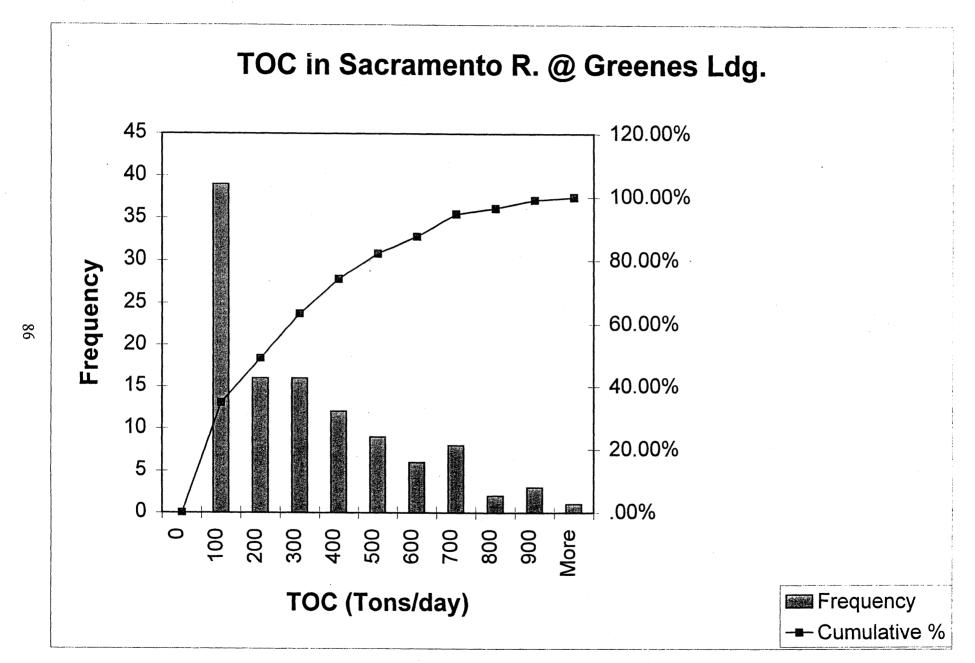
Figure 3-11 shows monthly mean TOC concentrations, along with the range encompassed within one standard deviation above and below the mean. The period January through March appear to be associated with higher TOC concentrations. Figure 3-12 shows monthly TOC mass loads, and the range of one standard deviation above and below the mean. Mass loads tend to be higher in February and March.

Figure 3-13 and Figure 3-14 indicate that, based on limited data, wet months of dry years produce highest TOC concentrations and mass loads. This is contrary to observations in the Sacramento River where wet months of wet years are highest. The difference may be attributed to the relatively larger influence of agricultural drainage in the San Joaquin River watershed that results in less dilution during wet months of dry years. Concentrations are consistently higher than the 2.0 mg/L limit dictating the need for treatment studies by drinking water purveyors.

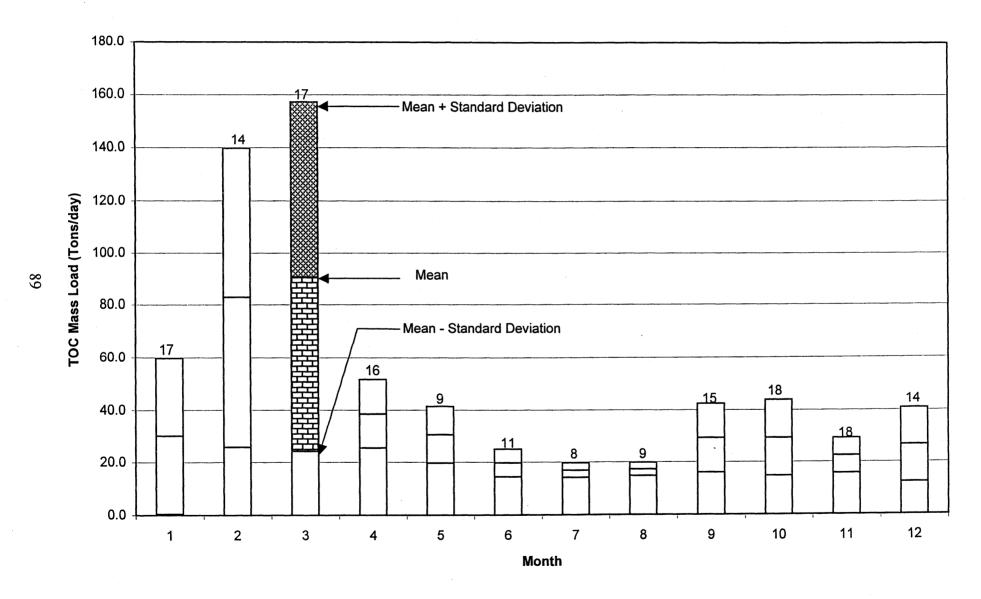
Recent studies of the San Joaquin River have indicated that on the order of half the TOC at Vernalis could be due to algae, and that some of this TOC will be lost through biological degradation by the time the water is diverted from the Delta for drinking water use. /6 This information suggests the summaries presented may somewhat overestimate the effect of TOC in the San Joaquin River on drinking water diversions.

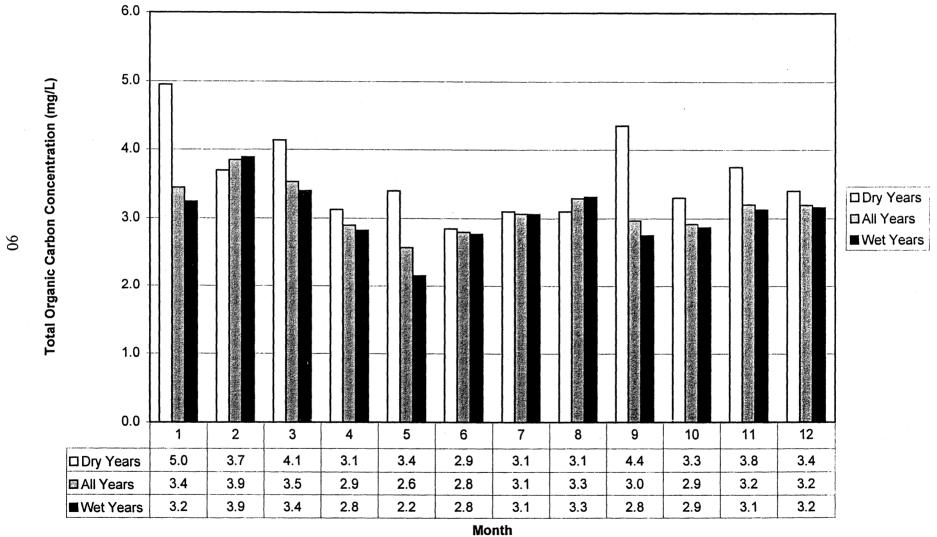
American River

Figure 3-15 is a historical depiction of limited TOC data collected from the American River at the Sacramento water treatment plant. The early years of record appear to be associated with lower loads than the latter years. This is probably explained by the dry hydrology of the earlier years compared to the wet hydrology of the latter. Figure 3-16 demonstrates that TOC concentrations are generally below the 2.0 mg/L threshold dictating the need for additional treatment effort by drinking water purveyors; and, seems



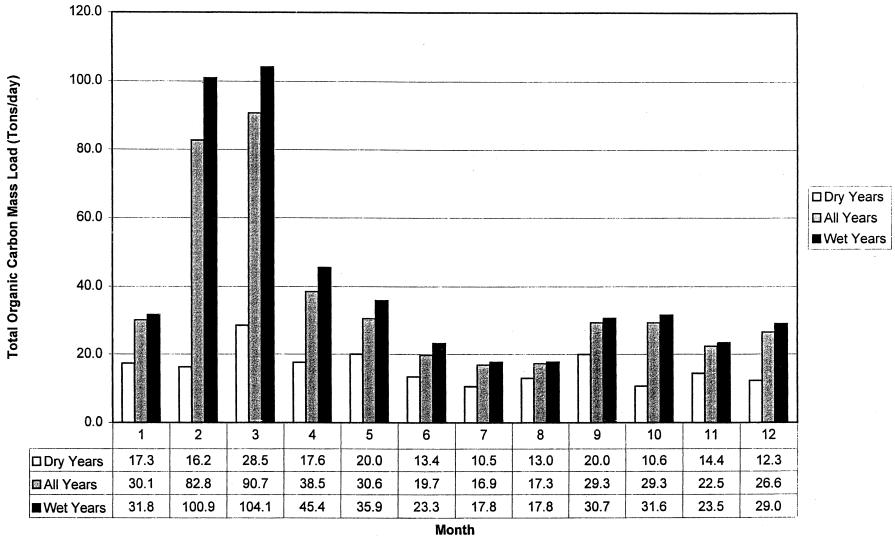
Total Organic Carbon in S.J.R. nr. Vernalis





TOC in S.J.R. nr. Vernalis

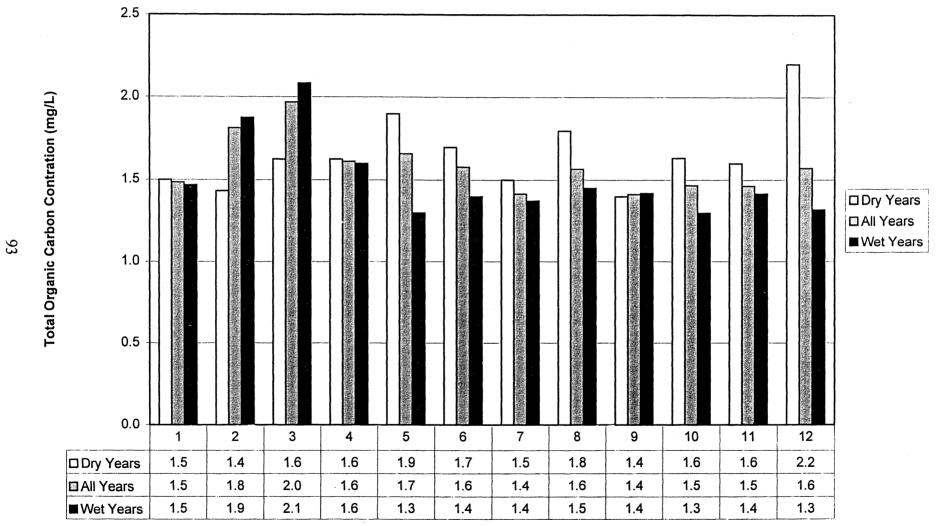
TOC in S.J.R. nr. Vernalis



91

1000

TOC in American R @ WTP



apparent that the range of concentrations experienced is more narrow than is the case for the Sacramento and San Joaquin Rivers. Loadings, depicted in Figure 3-17, indicate a strong relationship with flow, the wet months predominating, especially during wet years. Frequency distributions depicted in Figure 3-18 and Figure 3-19 show that most observed concentrations fall within the narrow range of 2 to 2.5 mg/L, and within a 10 to 40 Ton/day range of loadings.

Discharges

Data for Sacramento and Stockton storm water, Sacramento Regional County Sanitation District, and Delta island drainage were analyzed.

City of Sacramento Storm Drainage

Based on 43 storm drain samples collected from three Sacramento locations over the period March 1995 through September 1998, the average TOC in Sacramento storm drain samples was 12.8 mg/L with a standard deviation of 9.7 mg/L.

Stockton Storm Drainage

Based on 94 storm drainage samples collected from various Stockton locations, the average TOC concentration in this drainage was 14 mg/L. A load estimate is not presently available.

Sacramento Regional Waste Water Treatment Plant

Very limited data from three samples collected in April 1999 indicate an average TOC concentration in the plant effluent to be about 21 mg/L. During this period, plant flows averaged about 156 mgd (242 cfs), which yields an estimated mass load of about 14 Tons/day of TOC.

Delta Island Drainage

Based on over 400 samples collected from 15 Delta islands, drainage from these islands average about 19 mg/L and contributes an estimated 40 Tons/day of TOC. Figure 3-20 demonstrates that concentrations tend to reach a maximum in February, probably associated with the annual cycle of soil leaching for reducing salt in island soils. Loads, reflected in Figure 3-21, also reach maxima during February, with dry years being characterized by both higher concentrations and loads. A smaller maximum load pattern is seen in July, which is probably associated with residual irrigation water discharged to Delta channels during the growing season.

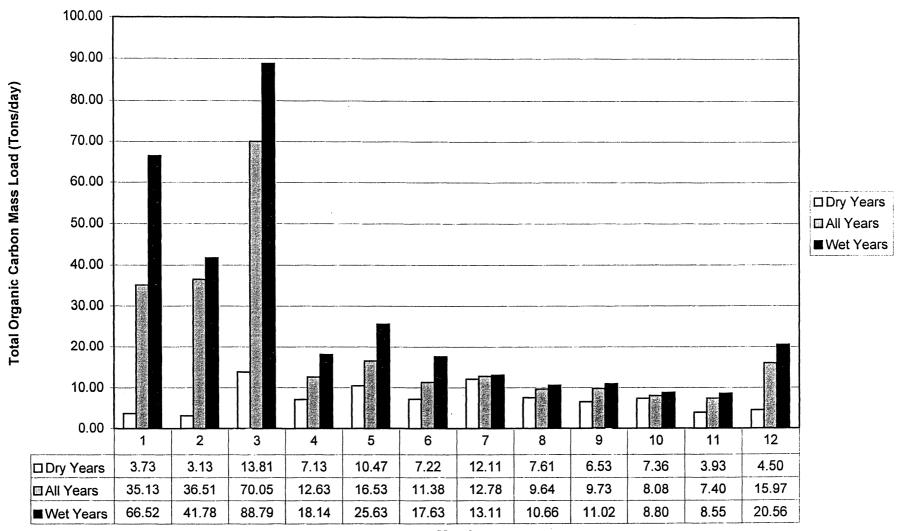
Diversions

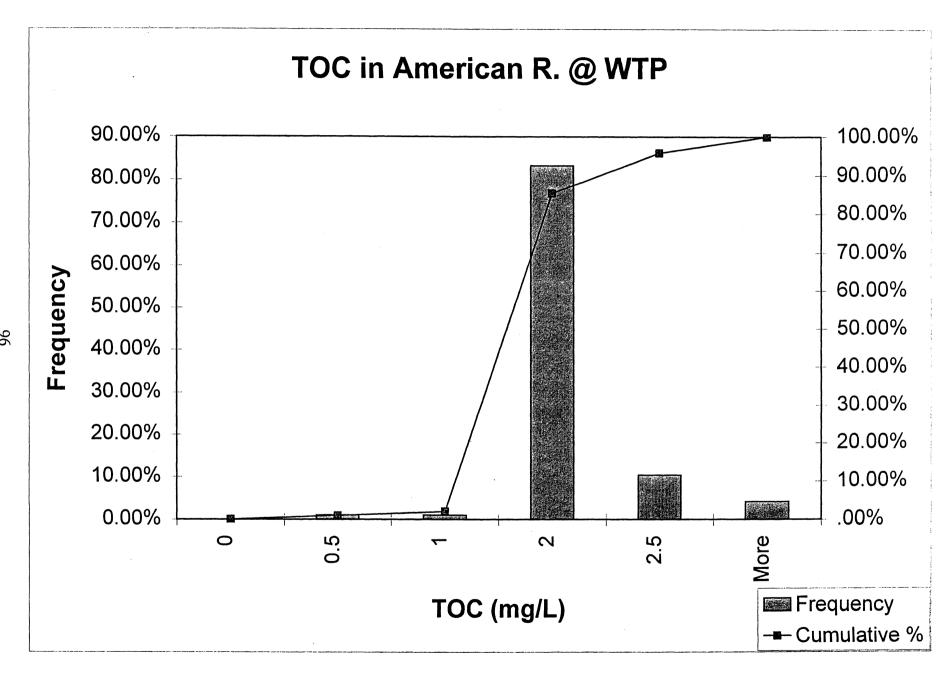
Please see the discussion in the DOC section for a description of the major drinking water supply diversions from the Delta.

North Bay Aqueduct, State Water Project

Figure 3-22 depicts monthly average TOC concentrations during different hydrologic conditions. Concentrations tend to be highest in wet months of all years, as is the case with DOC. Average concentrations over 12 mg/L have been observed, which is

TOC in American R @ WTP





TOC (Tons/day)

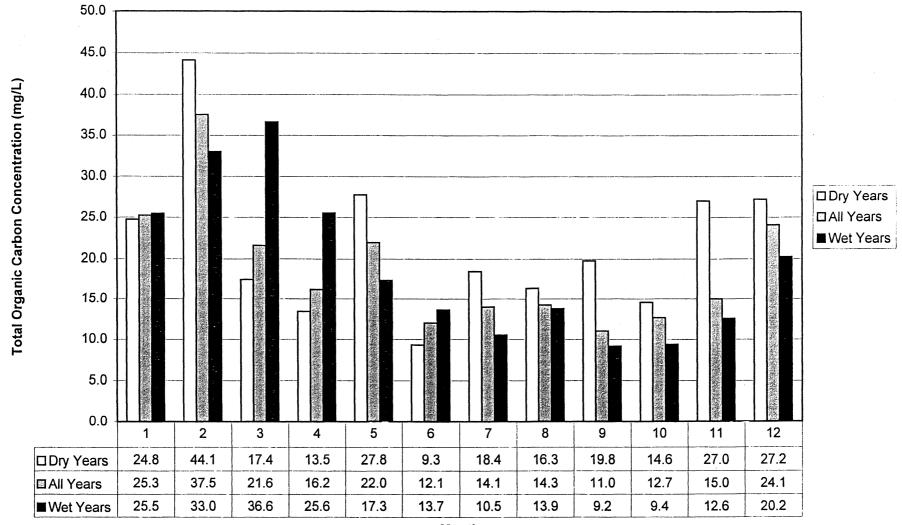
TOC in American R @ WTP

45.00%

40.00%

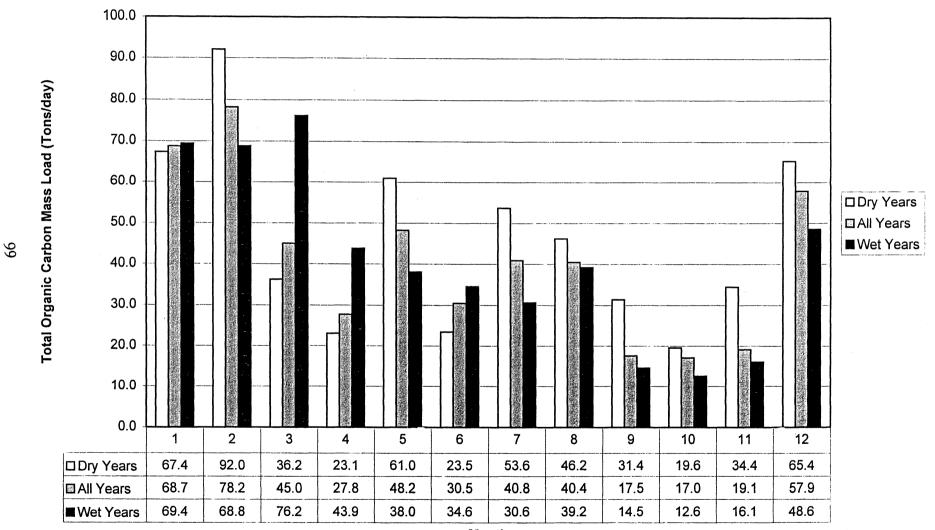
Cumulative %

120.00%



Month

TOC in Delta Island Drainage



considerably higher than is experienced by other diverters of drinking water supply from the Delta.

Figure 3-23 shows TOC loads by month for different hydrologies. As is the pattern with DOC at this location, load maxima are reached in the dry months of all years, with a peak being reached in the June-July period in most hydrologic conditions. The observation that peak loads are not associated with peak concentrations at this location indicates that different phenomena are at work than is the case in the Sacramento River at Greenes Landing and, which provides support to the hypothesis that local watershed influences are an important determinant of TOC in the North Bay Aqueduct.

California Aqueduct, State Water Project

Figure 3-24 shows the historical record of TOC at the H.O. Banks Pumping Plant. No clear trends of change are evident from the limited available data. Figure 3-25 and Figure 3-26 depict monthly average TOC concentrations and loads, respectively. Due to the limited data set available for analysis, the significance of these representations is uncertain. Frequency distributions for concentration and mass loads, depicted in Figure 3-27 and Figure 3-28, respectively, indicate most TOC observations fall within the 2 mg/L to 6 mg/L range, with the 3.0 mg/L to 3.5 mg/L range being the most commonly observed. Most loads occur in the 10 to 70 Tons/day range (keeping in mind that load is a function of pumping and does not represent a natural condition. The purpose of computing loads in diversions is only to provide an indication of the mass of material with which a drinking water purveyor must contend)

Contra Costa Water District Pumping Plant #1

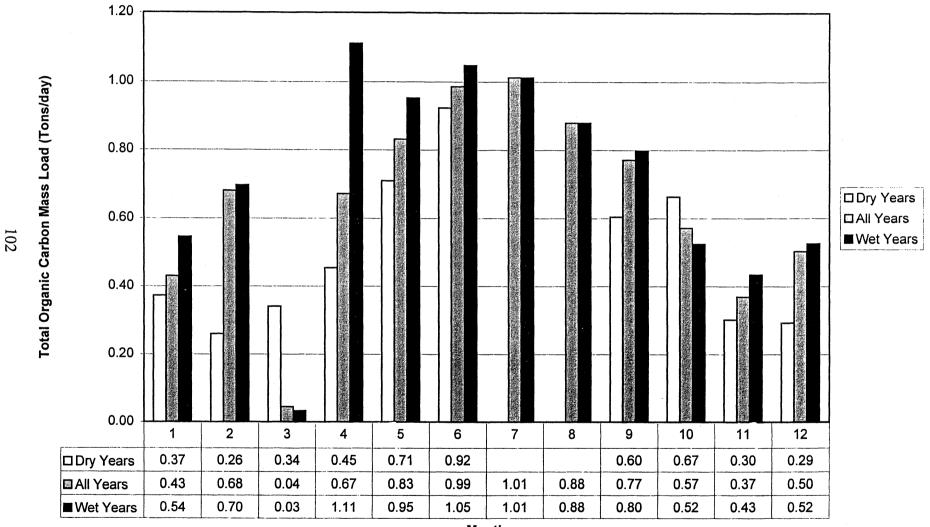
Figure 3-29 depicts the limited TOC data available for Pumping Plant #1. Figure 3-30 indicates that most TOC concentrations are observed in the 3 to 5 mg/L range, and Figure 3-31 indicates that loads most commonly fall within the range of 1 to 3 Tons/day. (The comparatively smaller load at Pumping Plant #1 as compared to Banks PP is a reflection of the smaller size of the CCWD facility, not an indication of better water quality.)

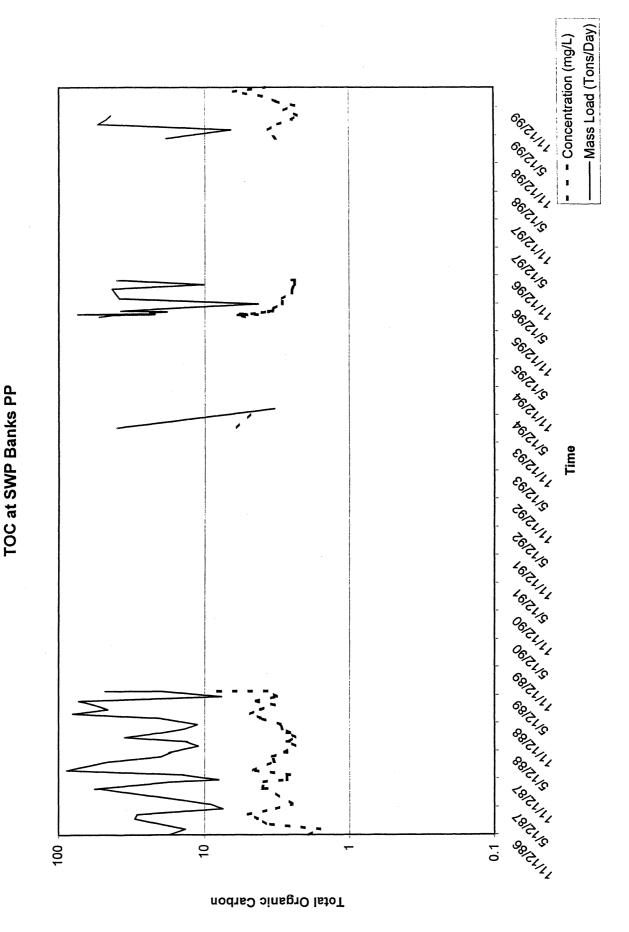
Delta Mendota Canal, Central Valley Project

Figure 3-32 depicts the very limited TOC data available at the DMC intake channel near Tracy Pumping Plant. Figure 3-33 and Figure 3-34 show computed monthly average TOC concentrations and loads under different hydrologic conditions. The limited available data do not support firm conclusions; however, the data do indicate that wet months are most important with respect to TOC concentrations and loads.

Figure 3-35 and Figure 3-36 demonstrate that TOC is most frequently measured in the range of 3 to 6 mg/L and 20 to 60 Tons/day.

TOC at SWP North Bay PP





2.8

2.4

1.5

4.9

4.3

3.3

Month

2.7

2.7

2.8

2.4

2.5

2.5

3.3

3.0

2.4

3.4

2.9

2.6

2.9

2.6

2.2

3.4

3.1

2.4

6.0

5.0

4.0

□ Dry Years

☐ All Years

■ Wet Years

4.4

4.3

4.0

4.6

5.1

5.7

3.9

4.2

4.3

3.7

3.5

3.3

104

□ Dry Years

☐ All Years ■ Wet Years

12.9

9.4

2.3

20.7

21.3

22.7

Month

13.4

30.7

48.0

35.6

42.3

45.7

70.0

60.0

50.0

□ Dry Years

■ All Years

■ Wet Years

63.0

63.0

38.8

39.5

40.7

43.9

36.2

33.3

33.6

27.4

18.2

105

□ Dry Years □ All Years

■ Wet Years

12

17.5

16.8

13.6

27.5

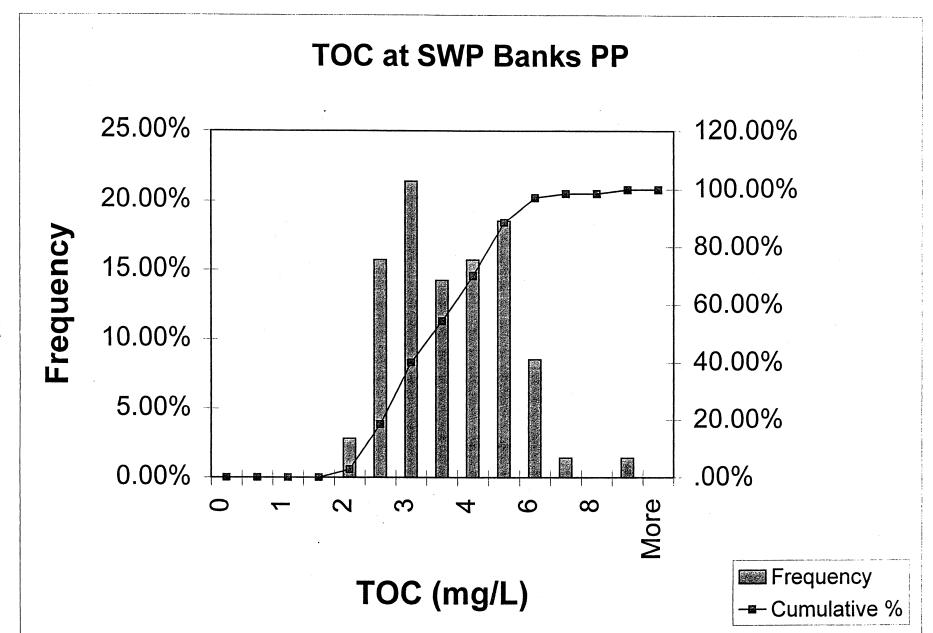
39.5

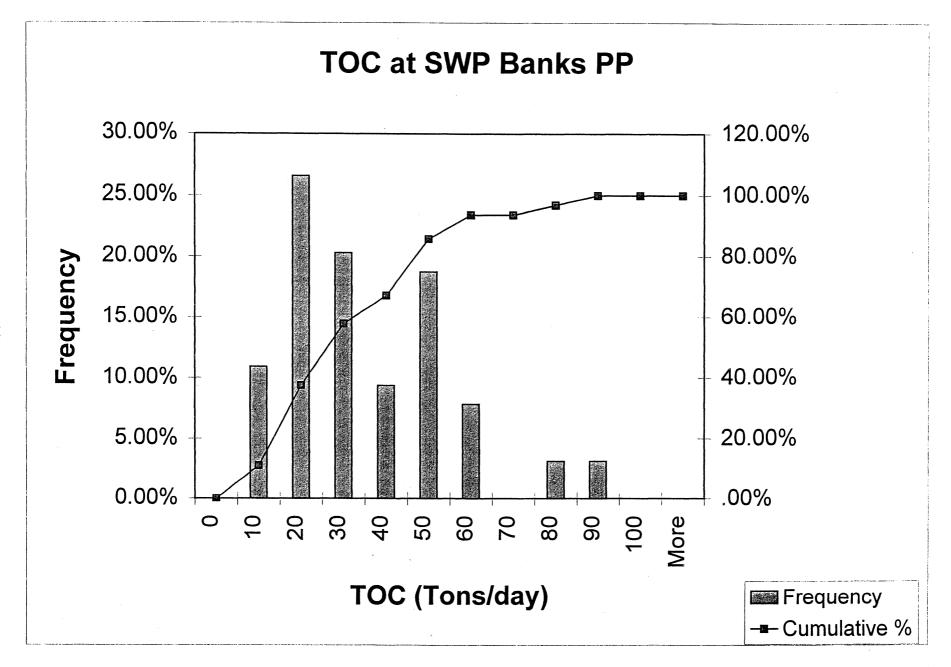
12.1

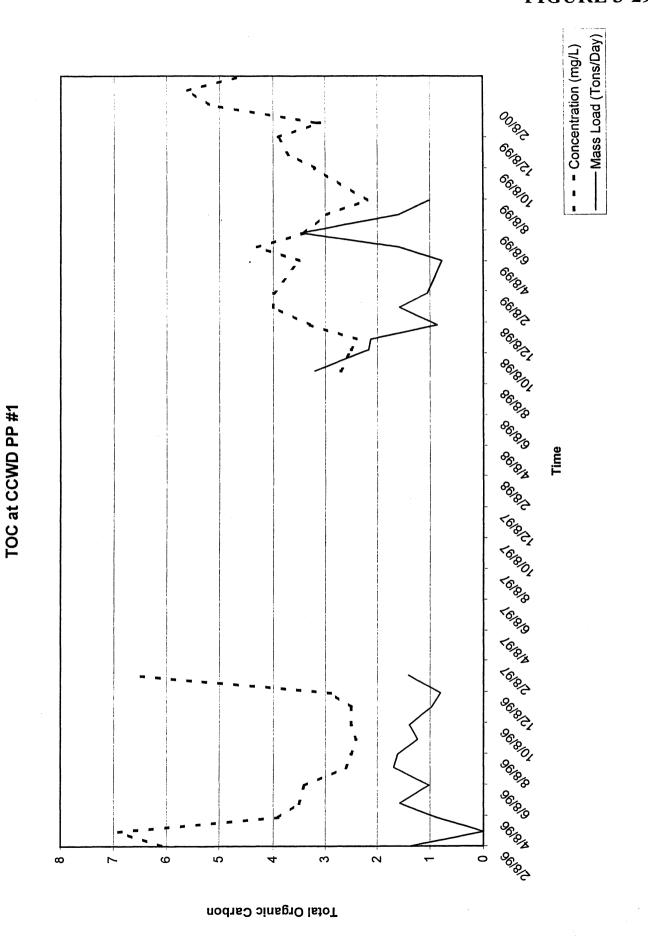
17.8

34.2

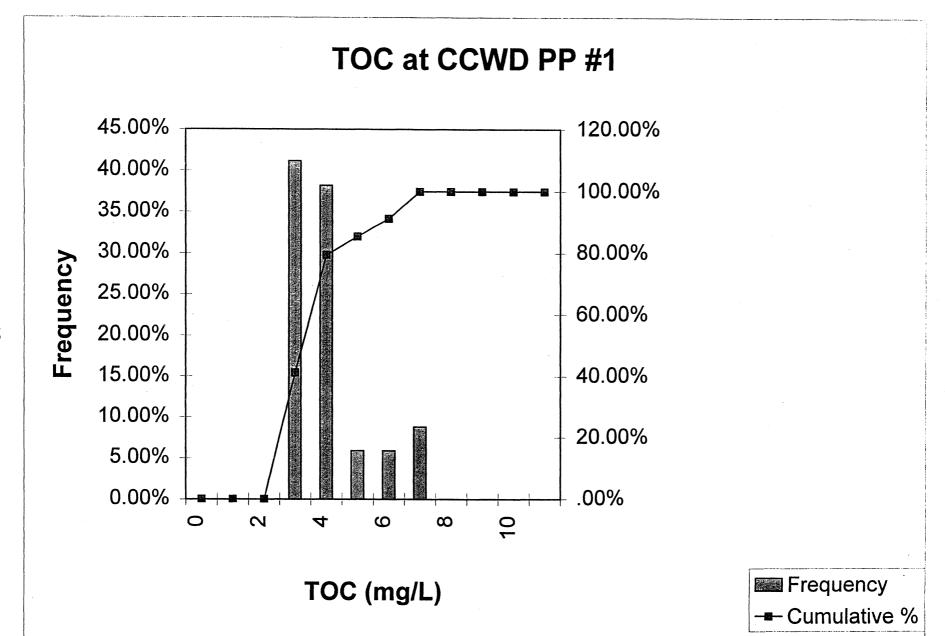
27.3

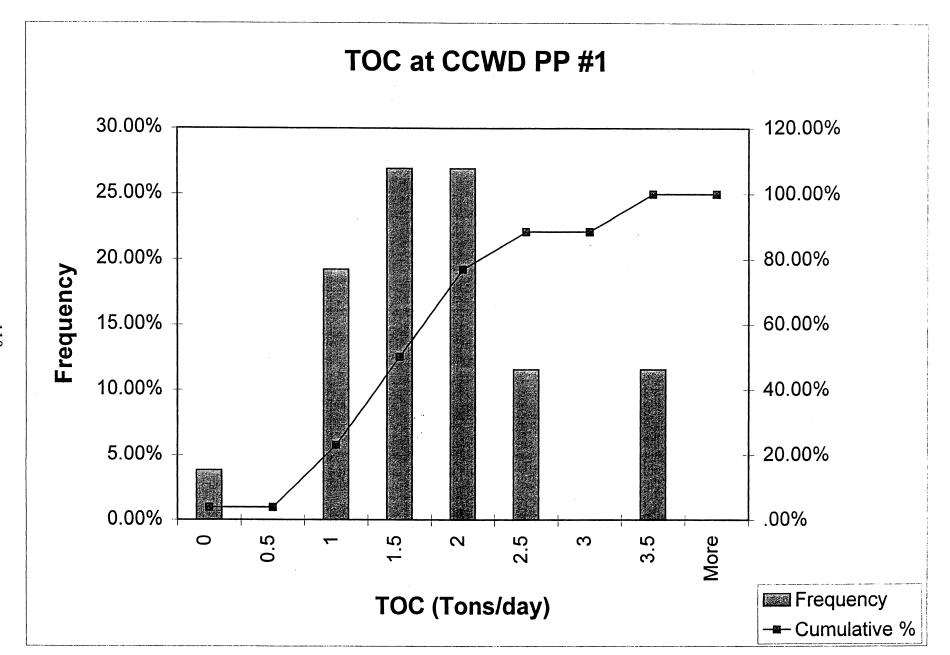


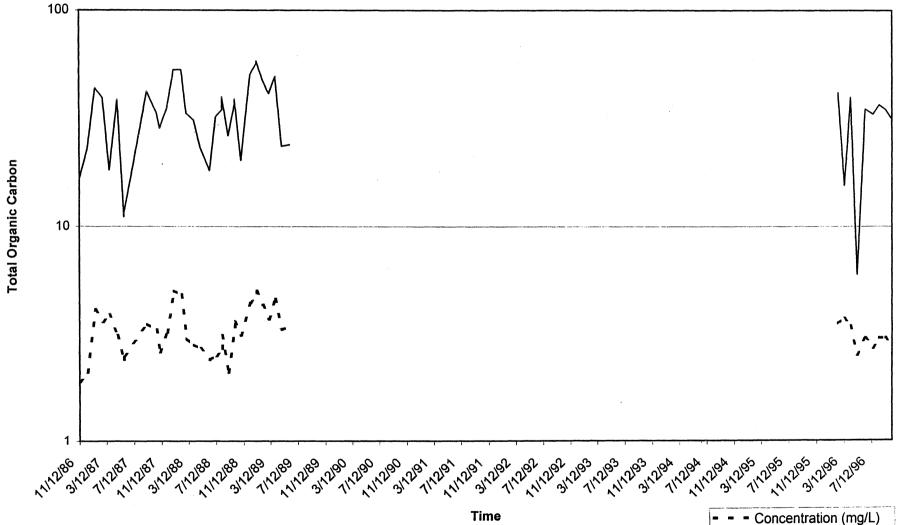




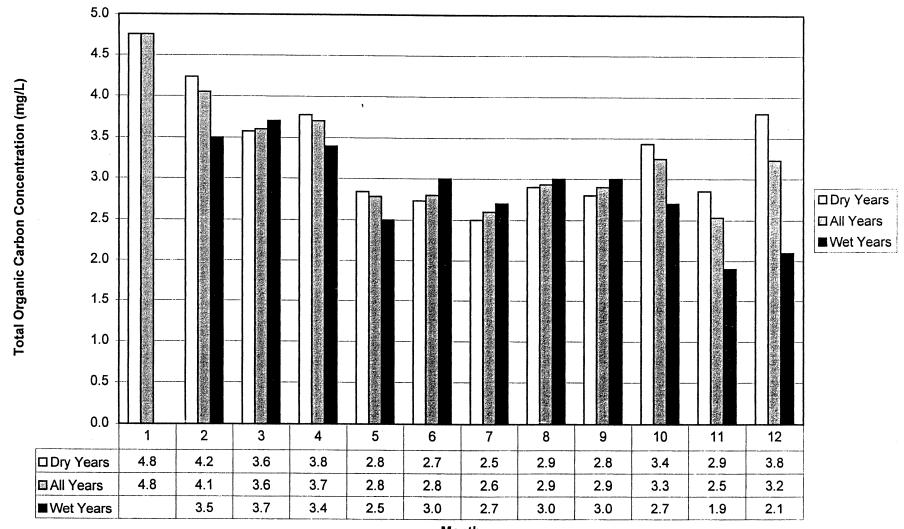
108



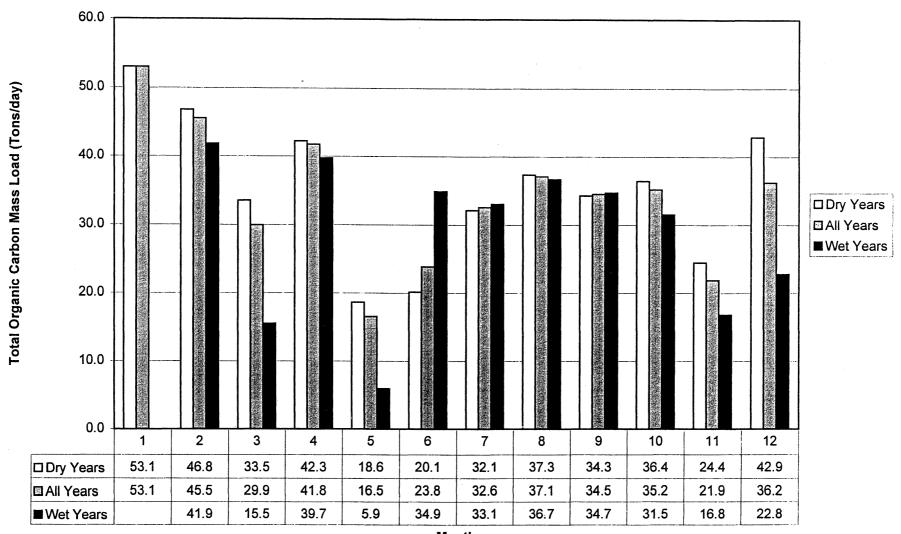


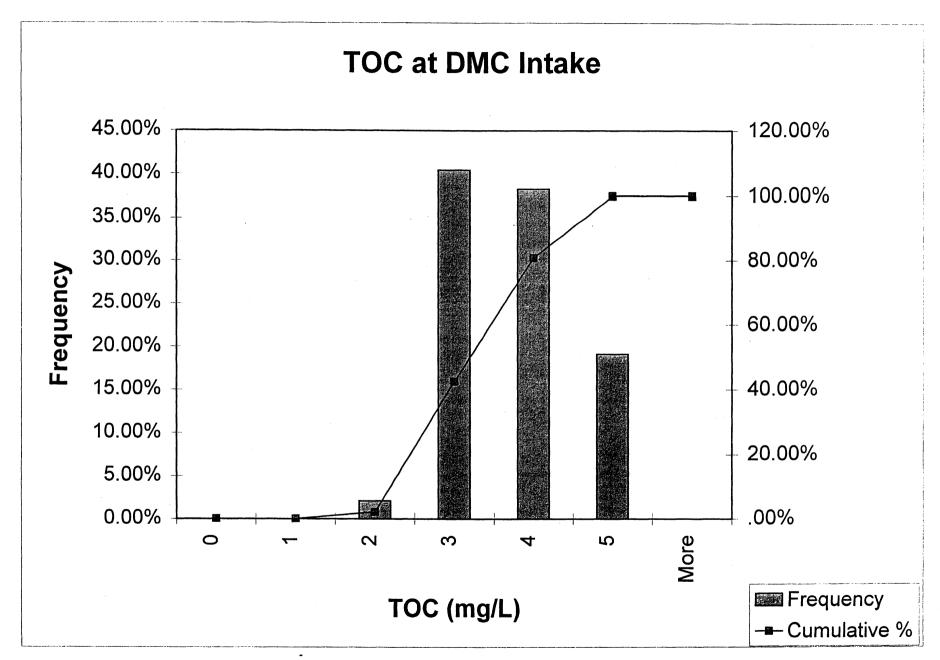


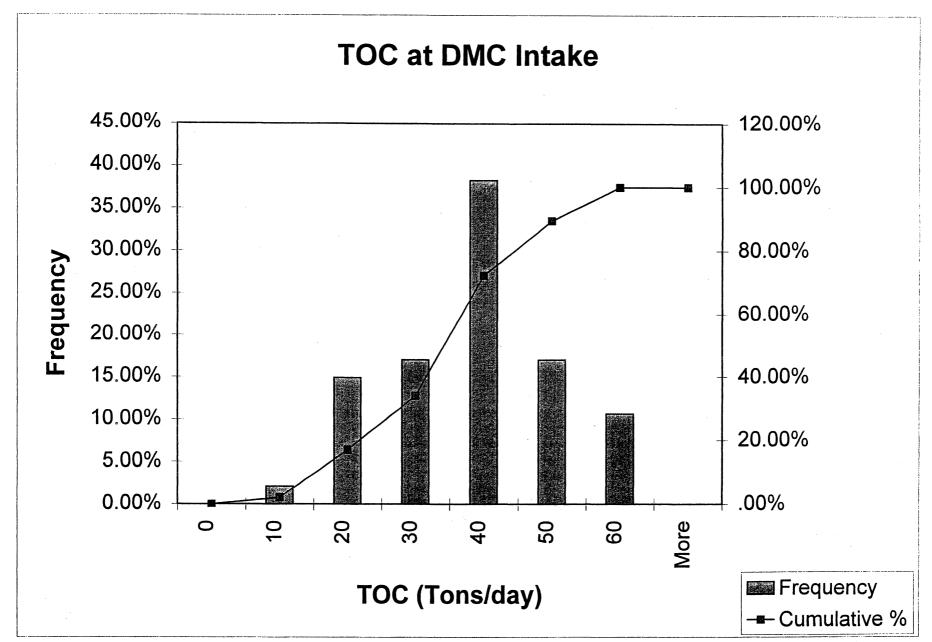
TOC at DMC Intake



TOC at DMC Intake







Bromide

Bromide is important in drinking water supplies because it reacts with organic carbon and chemical oxidants (chlorine, ozone) used for disinfection to produce brominated organic disinfection byproducts. Some brominated byproducts are believed to be harmful and, in some cases, perhaps more harmful than other disinfection byproducts produced in drinking water.

The Pacific Ocean is a major source of bromide in the Delta system, due to sea water influence on drinking water supplies taken from the Delta. Figure 4-1 summarizes bromide loads observed in inflows and discharges to the Delta. The San Joaquin River and Delta island drainage appear to be the most important sources. However, it is important to realize that both the San Joaquin River and Delta island drainage recycle bromide that is already in the system. Irrigation water containing bromide flows onto Delta islands from the adjacent channels and is concentrated through evaporation and plant transporation, then discharged in island drainage. Similarly, water is diverted into the San Joaquin Valley through the Delta Mendota Canal, used for irrigation in the Valley, then returned to the Delta as drainage through the San Joaquin River. Therefore, although there are probably intrinsic sources of bromide on Delta islands and in the San Joaquin Valley, it is likely that much of the bromide observed in island drainage and in the San Joaquin River is simply concentrated from the applied irrigation water.

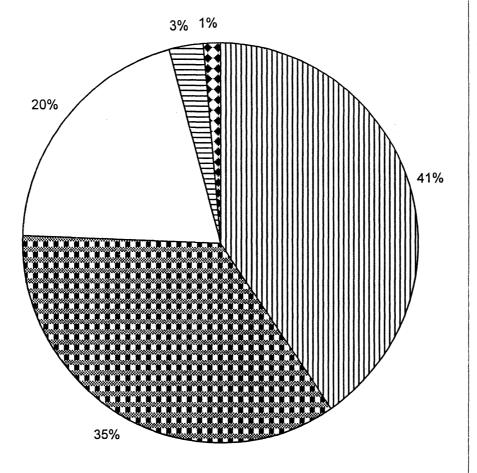
Figure 4-2 shows overall concentrations and mass loads of bromide that have been observed at various locations in the Delta. Note that the computed load at Mallard Island in the western Delta, based on Net Delta Outflow, indicates that loads of bromide at that location are two orders of magnitude higher than at the fresh water locations. This is a clear indication of the importance of the ocean influence on bromide concentrations in the Delta. Evidence of bromide recycling through the DMC-San Joaquin Valley-San Joaquin River connection is seen in the computation that most of the bromide load in the San Joaquin River is accounted for by the load in the DMC. This computation was based on data collected under the Department of Water Resources' Municipal Water Quality Investigations Program which, because of its extensiveness, has been used to enhance comparability of data among the locations being evaluated in this study.

A previous estimate, based on continuous specific conductance (EC) and flow recordings at the DMC intake and at Vernalis, and computed bromide concentrations based on regression analyses of EC versus Bromide, indicated that about 80% of the load in the San Joaquin River near Vernalis is accounted for by the influent load through the DMC.

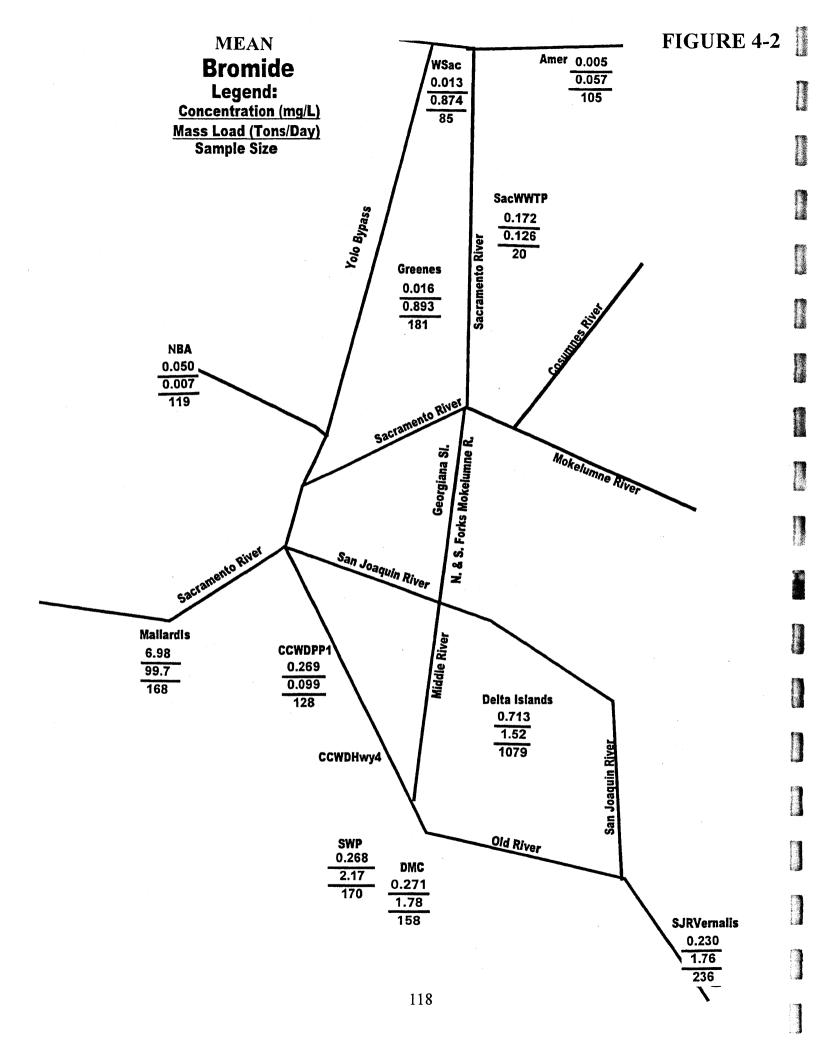
3/ The earlier estimate based on continuously recorded data is probably better than the one based on discrete samples used in the current analysis. In any case, both analyses make clear the fact that a large proportion of bromide load in the San Joaquin River must come from the Delta; and, the large "reservoir" of bromide present in the western Delta is a clear indication that the ocean must be a very important source of bromide in the system.

Delta Tributaries

Bromide concentrations are discussed in order of tributary size.



- San Joaquin R.
- Delta Islands
- ☐ Sacramento R.
- **Sac. WWTP**



Sacramento River

The Sacramento River is the largest fresh water inflow to the Delta but, despite its predominant flow, is not the most important source of bromide in drinking water supplies taken from the Delta.

West Sacramento Intake

Figure 4-3 summarizes historical data for bromide at the West Sacramento water treatment plant intake. No obvious trends of change are apparent. Figure 4-4, showing monthly average bromide concentrations over different hydrologic conditions, indicates that maximum bromide concentrations are reached during dry months of dry years, consistent with the concept of lower dilution capacity available for drainages to the system, primarily agricultural discharges to the river. Loadings, depicted in Figure 4-5 are highest in April of wet years, probably reflecting the high flows experienced during such times, even though concentrations in these periods are low. Frequency distributions appearing in Figure 4-6 and Figure 4-7 show that almost all observations of bromide concentrations fall in the 0.005 to 0.030 mg/L range, while almost all loads fall within a 0.5 to 2 Tons/day range.

Greenes Landing

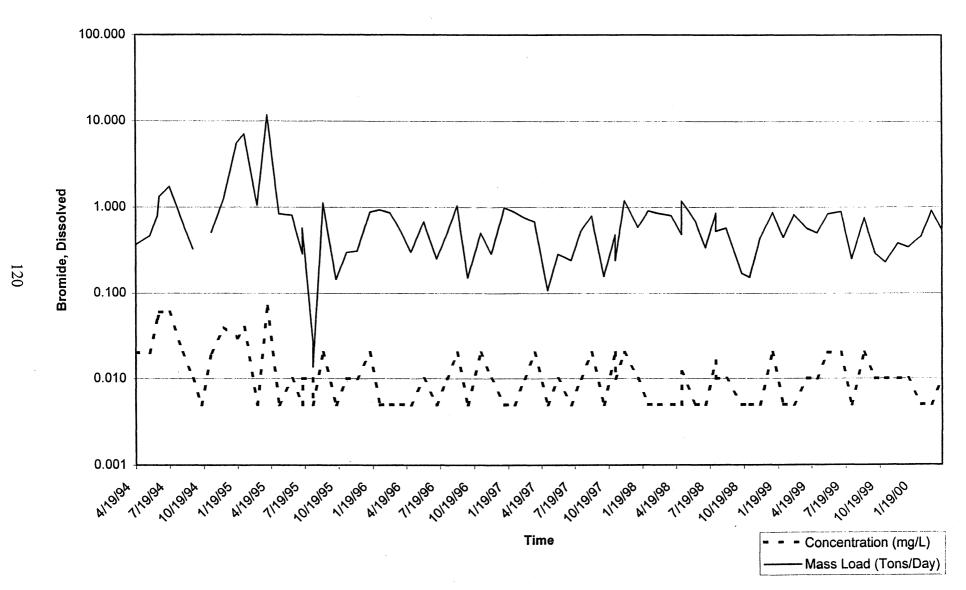
Figure 4-8 summarizes historical bromide concentrations at Greenes Landing, located about 8 miles downstream of the Freeport Bridge over the Sacramento River. The low that was measured in April 1996 is unexplained. River flow on that day was about 44,000 cfs, which is fairly typical for that hydrology.

Figure 4-9 depicts monthly average concentrations over different hydrologic year types. Maximum concentrations were reached in November of wet years; whereas, dry years are generally associated with higher bromide concentrations in most months. Loadings, depicted in Figure 4-10 are highest in wet months of wet years, and generally higher in wet months of all years, indicating the strong influence of increased river flow, even though concentrations during this period are not generally higher than in other months. Frequency distributions presented in Figure 4-11 and Figure 4-12 indicate the most often observations fall within the range of 0.010 to 0.030 mg/L and 1 to 3 Tons/day, respectively.

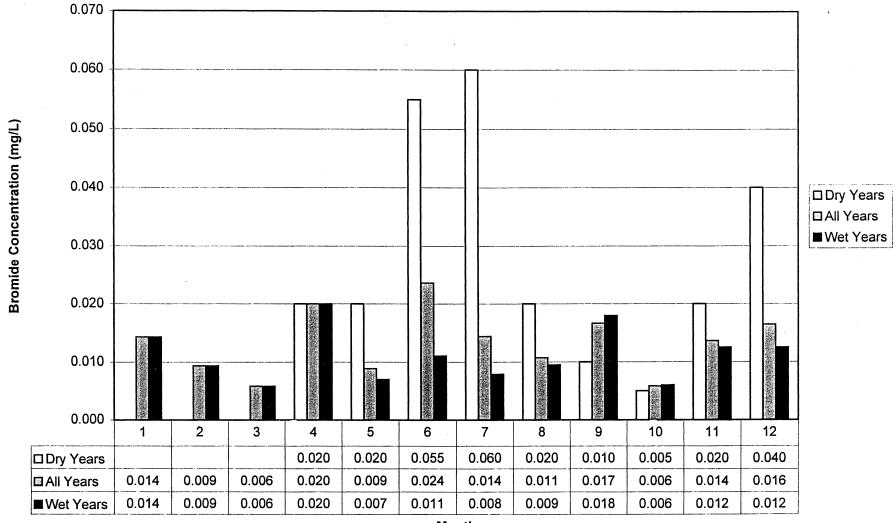
Mallard Island

Historical data for bromide at Mallard Island are summarized in Figure 4-13. Large fluctuations are apparent, reflecting the interaction of fresh water outflows and sea water intrusion. Figure 4-14 shows the pronounced effect of fresh water outflows on bromide at this location. As would be expected, in dry years lower flows available to repel seawater result in greater concentrations in all months, and particularly in the late fall when fresh water flows are minimal. The frequency distribution of concentrations (Figure 4-15) shows the most frequently measured concentrations fall in the 5 to 20 mg/L range (much larger than for the fresh water locations in the Delta).

Bromide in Sacramento R @ W.Sac. Intake

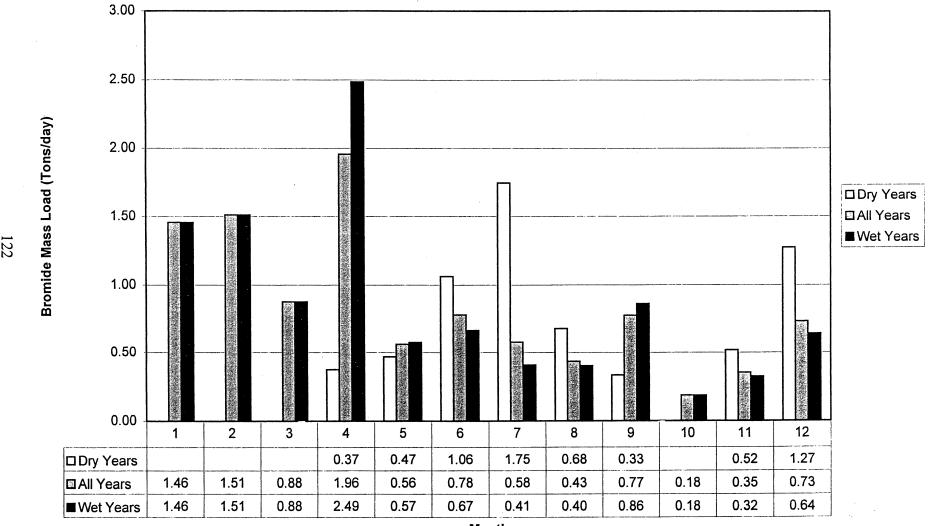


Bromide in Sacramento R @ W. Sac Intake

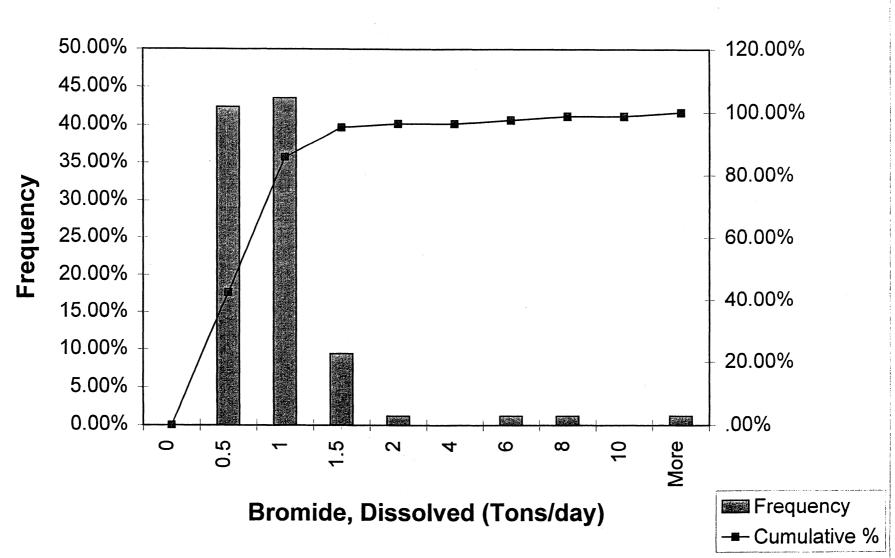


121

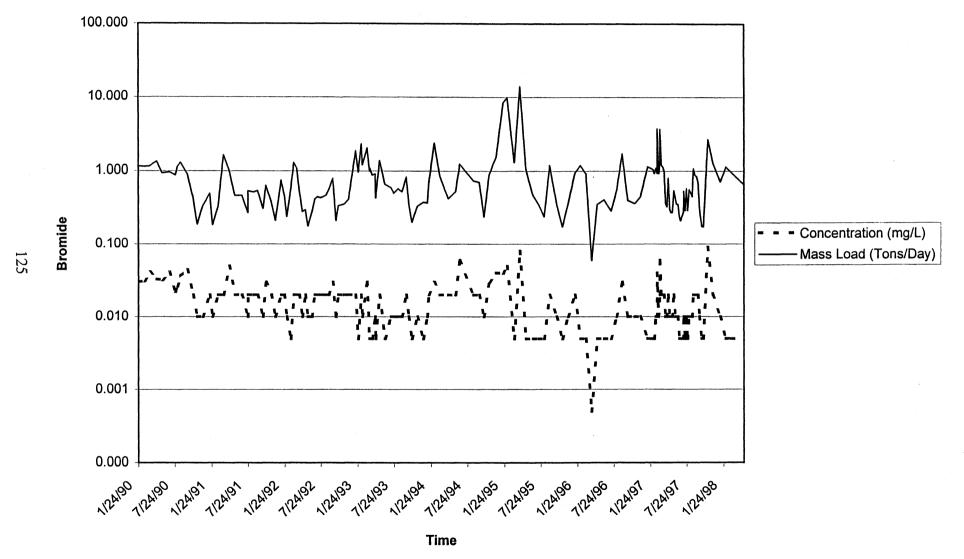
Bromide in Sacramento R @ W. Sac. Intake



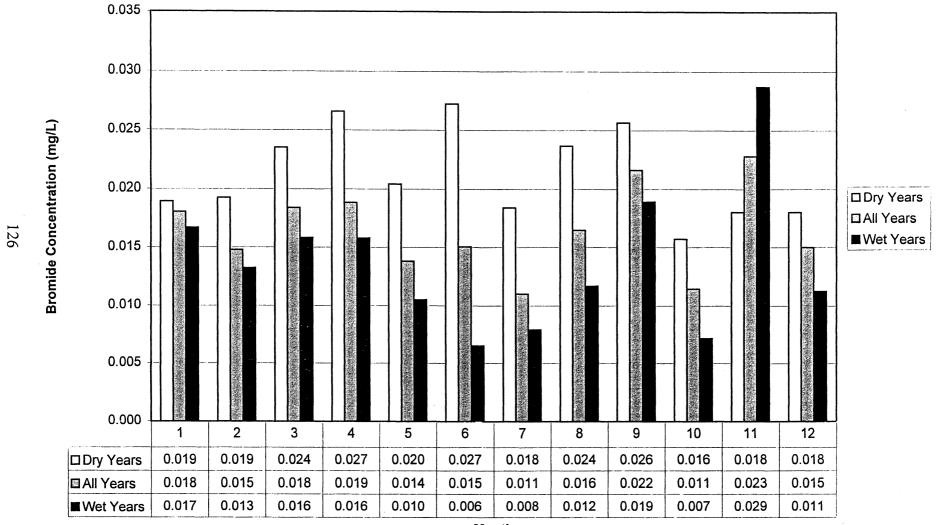


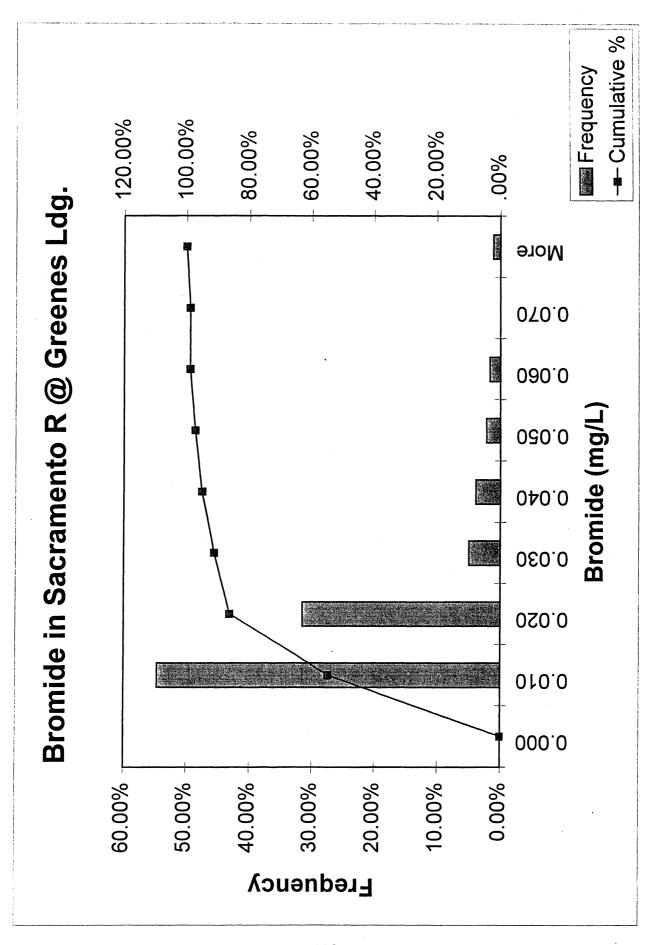


Bromide in Sacramento R @ Greenes Ldg.



Bromide in Sacramento R @ Greenes Landing





Bromide in Sacramento R @ Greenes Ldg.

129

80.00%

70.00%

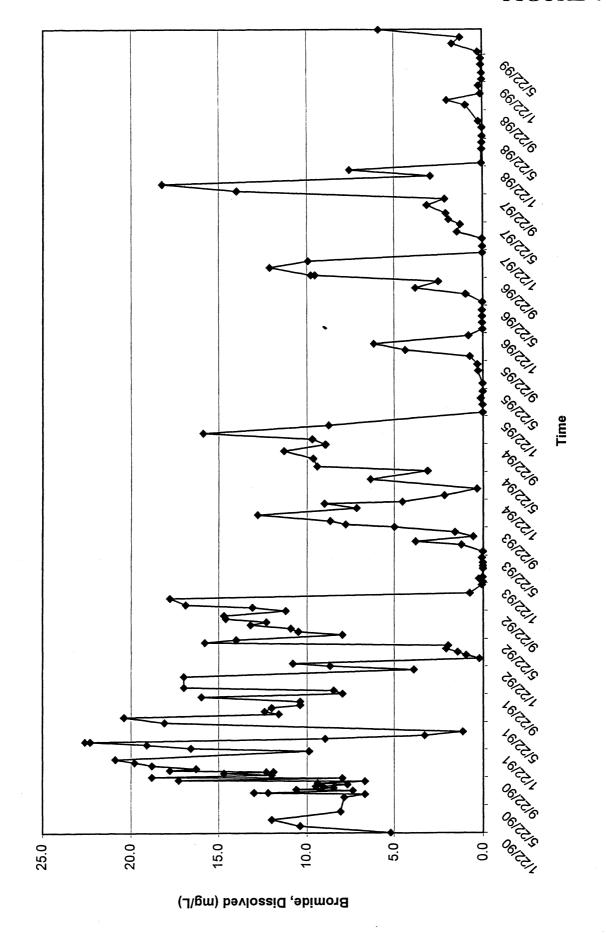
60.00%

50.00%

120.00%

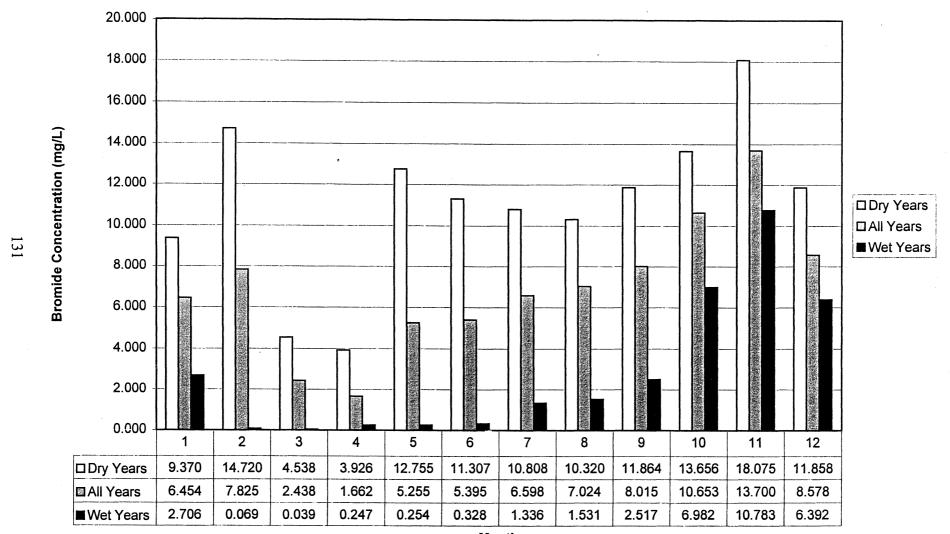
100.00%

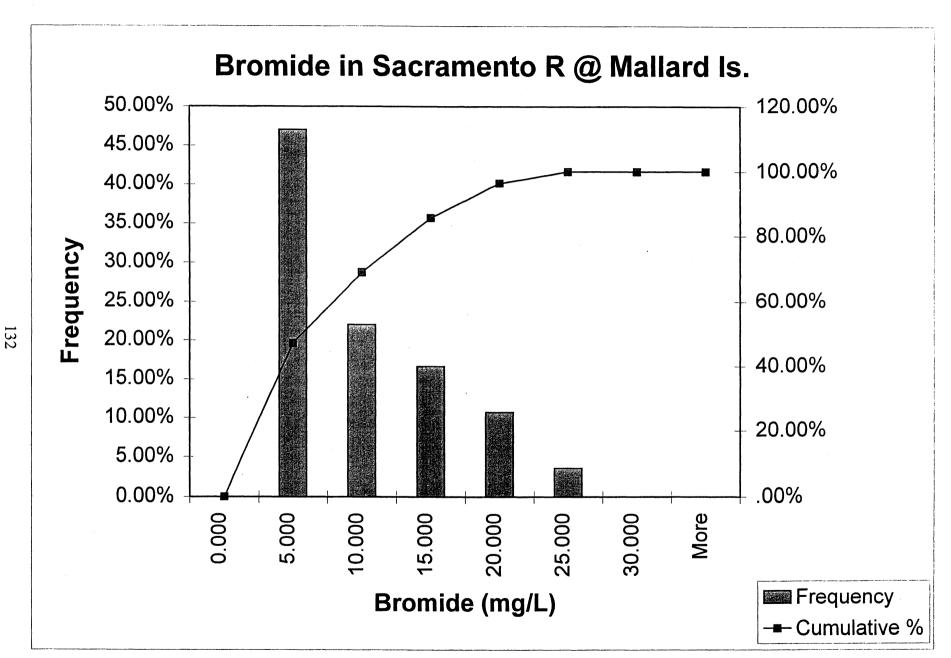
80.00%



Bromide in Sacramento R @ Mallard Is

Bromide in Sacramento R @ Mallard Is.





San Joaquin River

The San Joaquin River is the second largest source of inflow to the Delta, and is the largest source of bromide (keeping in mind that much or most of the bromide present in the river comes from the Delta through the DMC-San Joaquin Valley-San Joaquin River connection).

Figure 4-16 presents a summary of historical bromide concentrations and loadings measured in the San Joaquin River near the settlement of Vernalis. Concentrations tend to be higher during the first part of the record, during the period 1990-1994, and loads tend to be lower, than is the case in the latter part of the record. This difference is probably due mostly to the dry conditions prevalent during the early period while wet conditions prevailed during the latter period.

Figure 4-17, showing monthly average bromide concentrations over different hydrologic conditions, indicates that concentrations are significantly greater in dry years, which appears to be a clear reflection of reduced dilution of agricultural drainage into the river during periods when flows are low. Wet months of wet years produce minimum concentrations, indicating the beneficial effects of high river flow with regard to dilution capacity. Loadings, depicted in Figure 4-18 are highest in wet month of wet years, and are higher in most months of wet years. Concentrations in the 0.1 to .5 mg/L range are most often observed, as are loadings in the range of 1 to 4 Tons/day (Please refer to Figure 4-19 and Figure 4-20, respectively).

American River

Figure 4-21 summarizes historical bromide concentrations and loads measured in the American River at the intake to the Sacramento water treatment plant. The flat concentration curve indicates concentrations are most often below the minimum reporting level. The load estimate is based on the assumption that, where bromide concentrations are below the reporting limit, actual concentrations are half the limit. The loading calculation thus produced is speculative, and probably overestimates the actual loading.

Figure 4-22 demonstrates that bromide is usually detectable at this location only during April and May. Based on flow patterns, Figure 4-23 suggests that the wet months of wet years are associated with maximum bromide loads, although those loads are certainly low.

Discharges

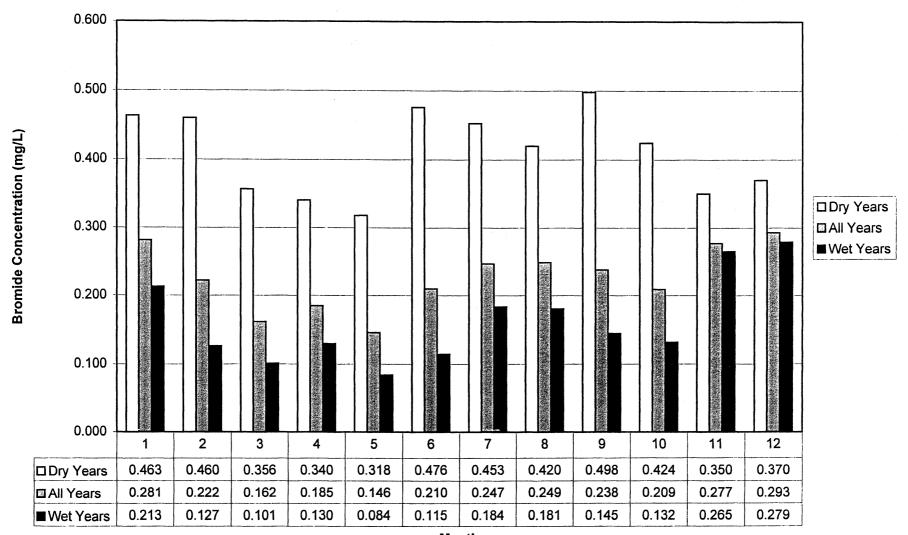
Sacramento Regional Waste Water Treatment Plant

Bromide data for the treated effluent of the Sacramento Regional Plant are quite limited, consisting of 20 samples collected during March and April 1998. Based on this very small data set, the average bromide concentration in the effluent was estimated to be 0.172 mg/L and the average loading to be 0.126 Tons/day. Based on this limited sample set, neither concentrations nor loadings of bromide from this source appear to be highly significant, keeping in mind that some bromide will have been present in the water taken from the river that was later returned through the waste water stream.

-Mass Load (Tons/Day) Concentration (mg/L) CO ECOLO 66/67/4 60/62/1 ob solo 86.67.45 86/CZ/V 16/52/6 (6/6/s (o/62/1 163/09 *GEO/G 60/67/4 ^{26/62/6} JOSON S 06/5/5 OFEEL 0.010 10.000 0.100 1.000 Bromide, Dissolved

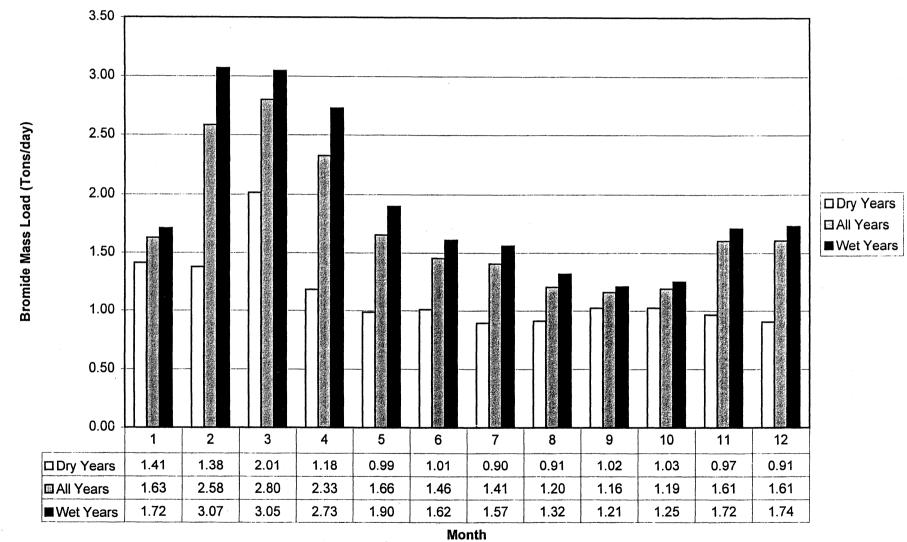
Bromide in S.J.R. nr. Vernalis

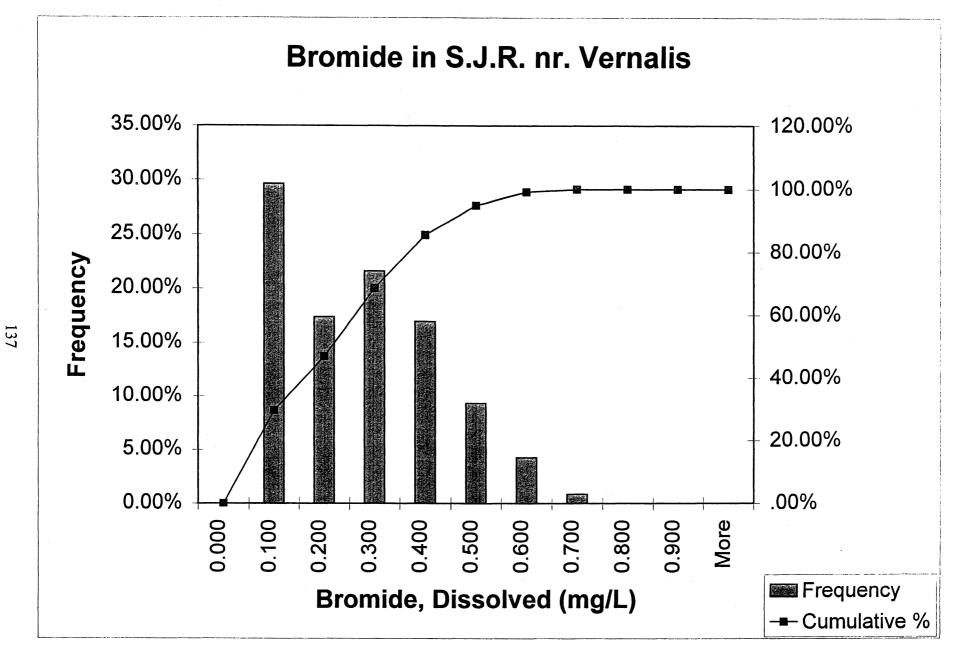
134

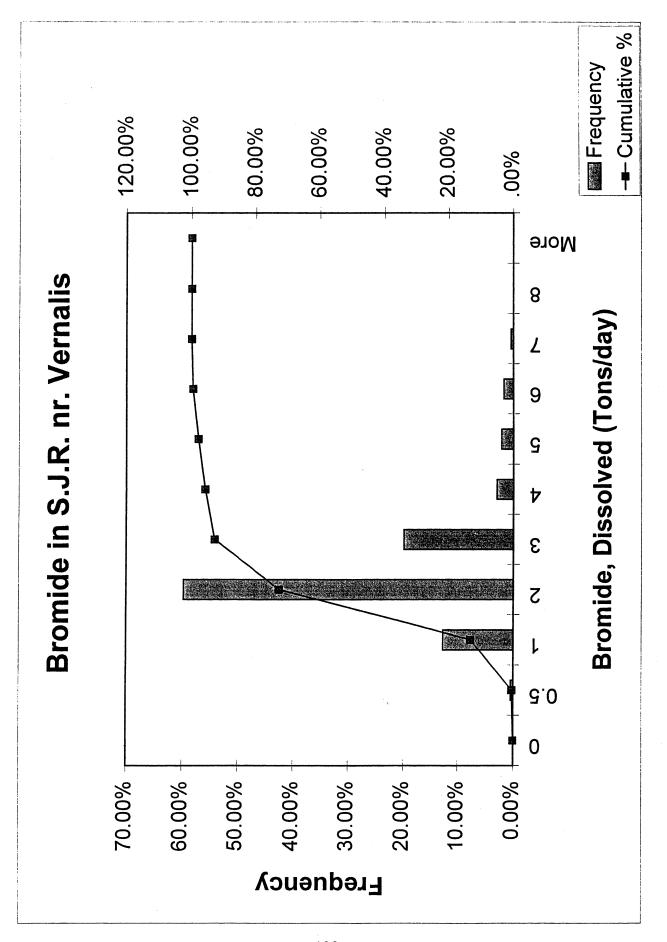


Month

Bromide in S.J.R. nr. Vernalis

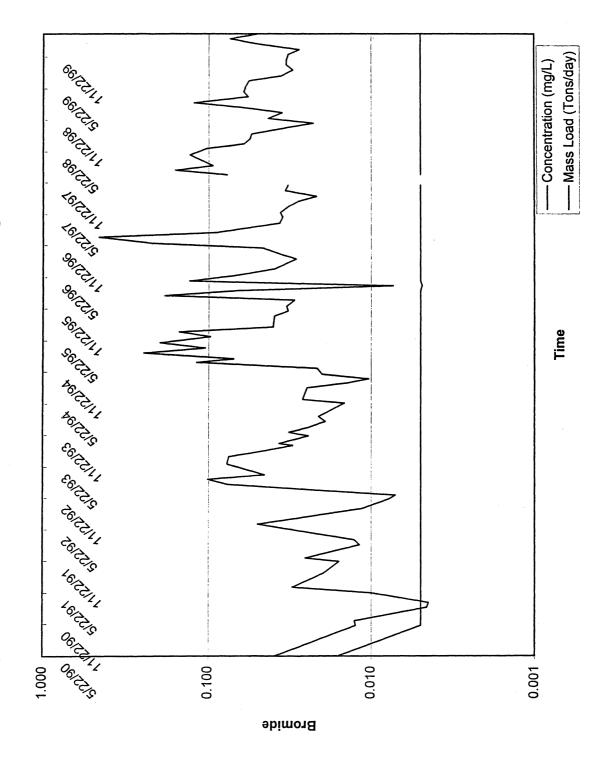




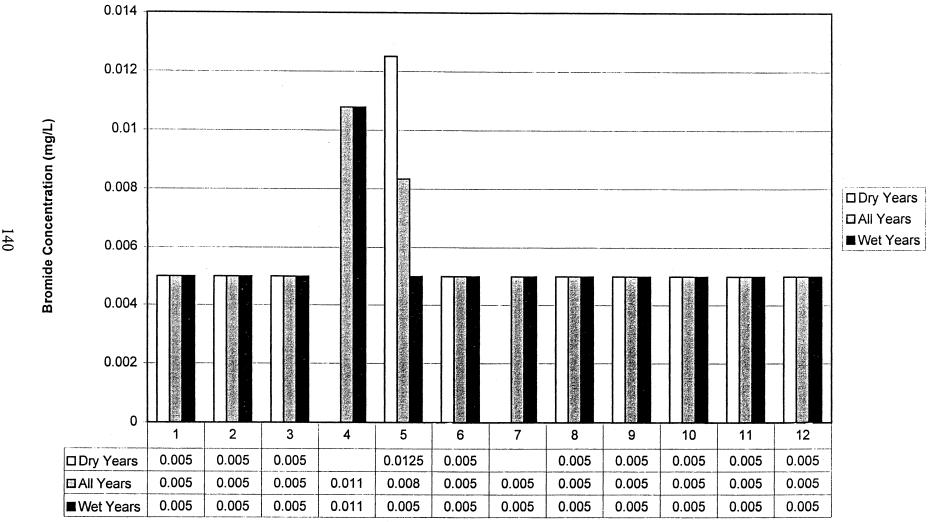


Bromide in American R. @ WTP

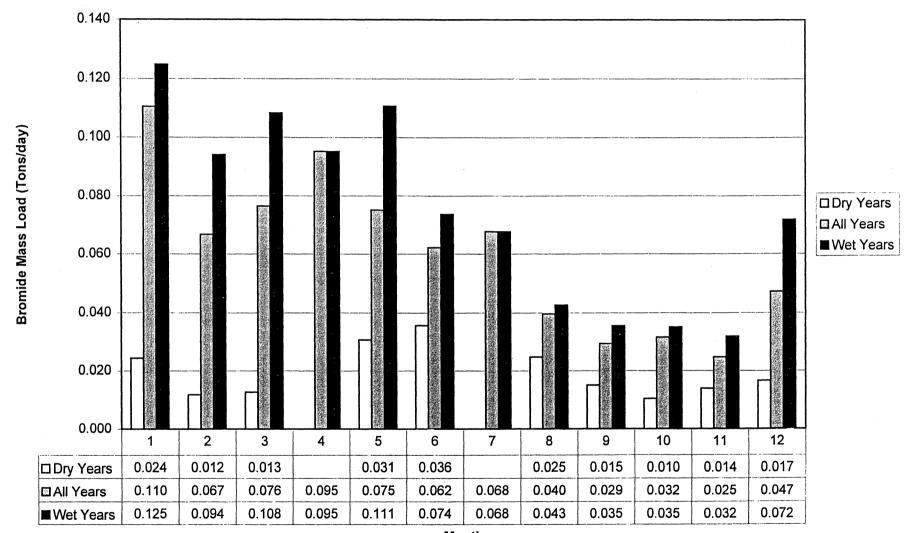
E V



Bromide in American River @WTP



Bromide in American R @ WTP



141

Delta Island Drainage

Drainage from Delta islands contains significant concentrations of bromide that constitute a significant load to Delta channels. Based on over 1000 measurements on 15 islands, bromide concentrations in island drainage appear to average about 0.713 mg/L and to produce a load of about 1.52 Tons/day. Because agricultural practices on the islands concentrate dissolved solids in the applied water, it is not certain whether significant intrinsic sources of bromide exist on some islands or whether the bromide appearing in the drainage water is practically all from concentration of channel water. Empire Tract is one Delta island that is known to have a connate (ancient sea water) source of bromide, but most Delta islands are believed not to have such sources. CALFED published evidence from a study by Metropolitan Water District of Southern California that indicated drainage for Empire Tract comprises only about 3 percent of total island drainage and, therefore, even if connate water from this source contributes "new" bromide to the system, the contribution is minimal. 4/

Figure 4-24 shows monthly average bromide concentrations measured in Delta island drains through different hydrologic conditions. Concentrations in September are at a maximum in all hydrologic year types. Loadings, shown in Figure 4-25 also indicate September is an important month. This period probably represents release of residual irrigation water. The elevation of concentrations and loads observed in March of dry years probably reflects release of leaching water to Delta channels, where leaching in dry years concentrates salts in the drainage.

Diversions

The following discusses bromide concentrations and loads in water supplies diverted from the Delta for drinking water supply.

North Bay Aqueduct, State Water Project

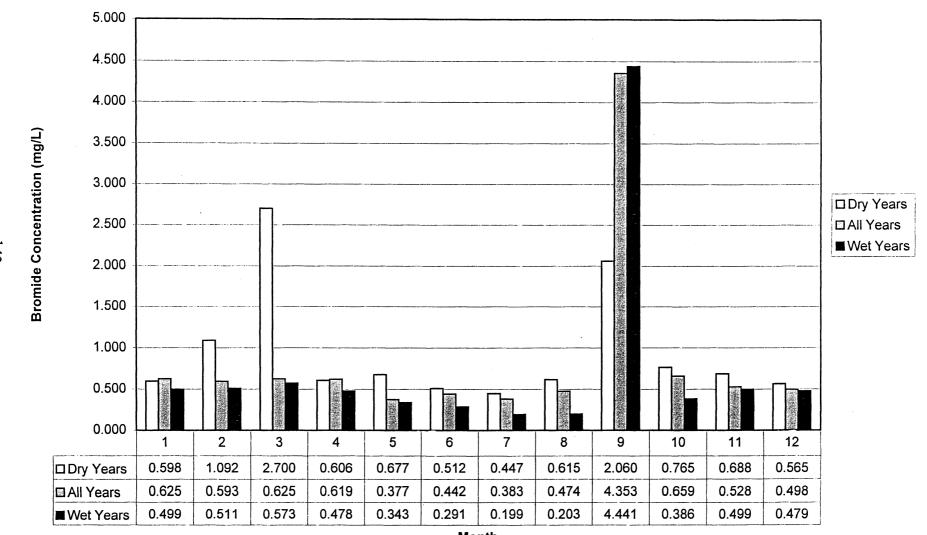
Figure 4-26 is a historical summary of bromide data collected at the Barker Slough Pumping Plant intake to the North Bay Aqueduct of the State Water Project. The minima observed occur during winter periods, indicating dilution of salt concentrations by higher flows. Because the local watershed is known to have important effects on water quality at this location, it seems probable that precipitation in the watershed contributes to salt dilution during the months when minima occur.

Figure 4-27 indicates the spring and early summer months tend to be associated with somewhat larger concentrations, which is also reflected in loads (referring to Figure 4-28). The most frequently encountered concentrations and loads are in the range of 0.030 to 0.070 mg/L, and 0.002 and 0.012 Tons/day, respectively, as indicated in Figure 4-29 and Figure 4-30.

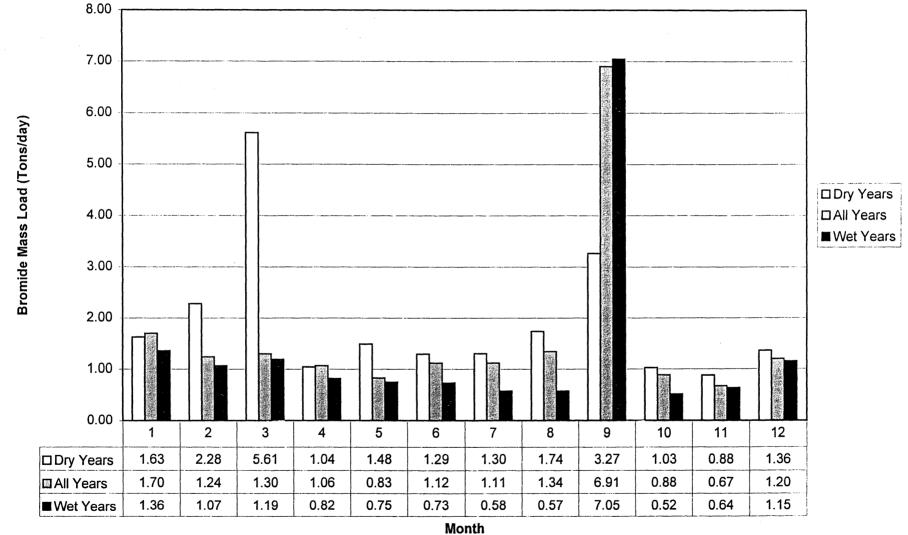
California Aqueduct, State Water Project

Figure 4-31 summarizes bromide concentrations measured at the H.O. Banks Pumping Plant in the south Delta. Trends of change are not apparent. Figure 4-32 demonstrates that all months of dry years are consistently associated with higher concentrations, whereas wet years are consistently associated with lower concentrations. This appears to

Bromide in Delta Island Drainage



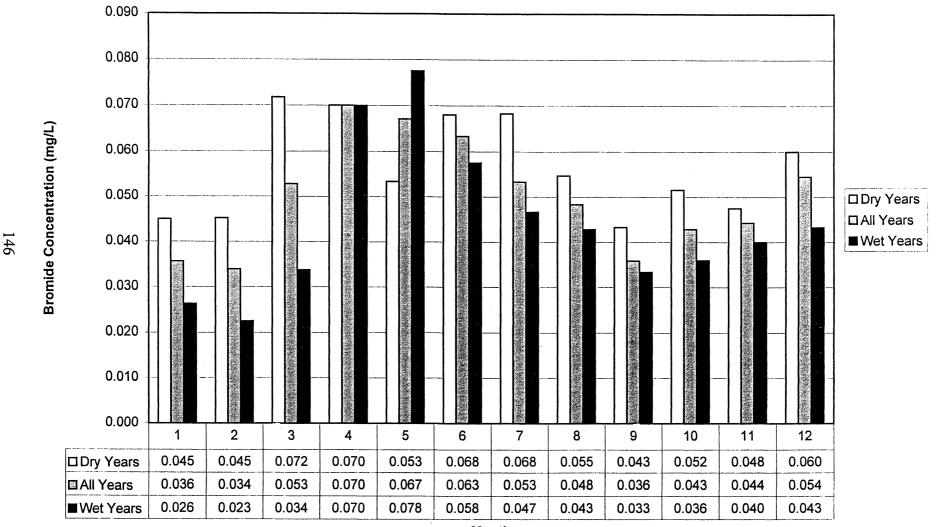
Bromide in Delta Island Drainage



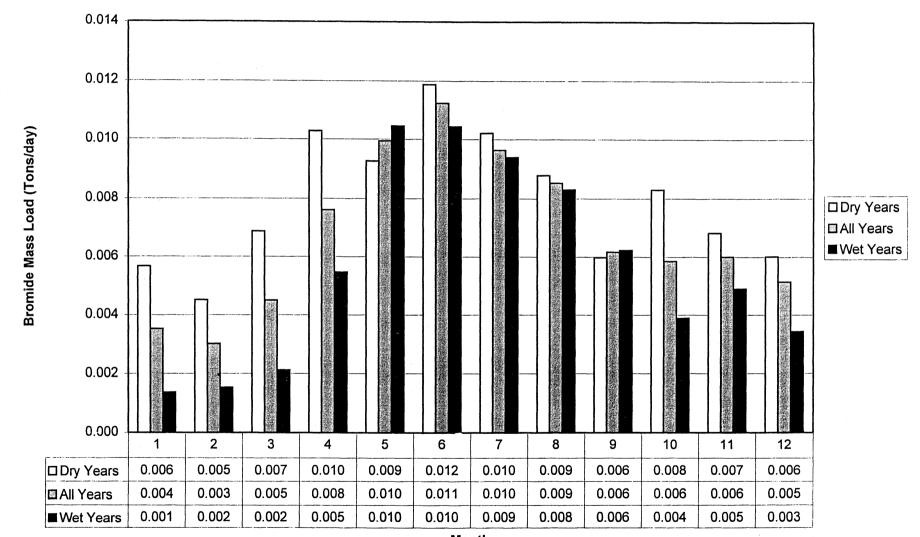
- Mass Load (Tons/Day) - - Concentration (mg/L) 66/12/2 86/12/01 86/12/2 10/12/01 16/12/0 16/10/2 96/12/01 96/12/9 %/_{12/2} 50/12/01 66/19/9 56/19/2 *6/12/01 46/12/9 E6/12/01 66/4/9 color. CO/12/01 26/12/9 6/4/4 18/12/01 16/12/9 6/19/2 06/12/01 06/12/9 06/12/2 0.000 0.100 0.010 0.001 1.000 Bromide, Dissolved

Bromide at SWP North Bay PP

Bromide at SWP North Bay PP



Bromide at SWP North Bay PP



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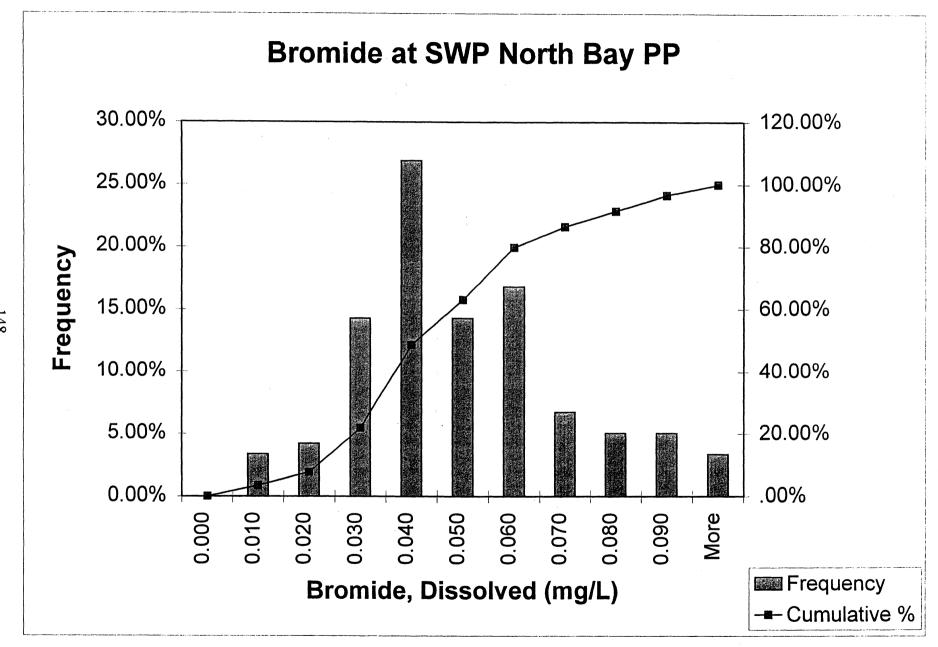
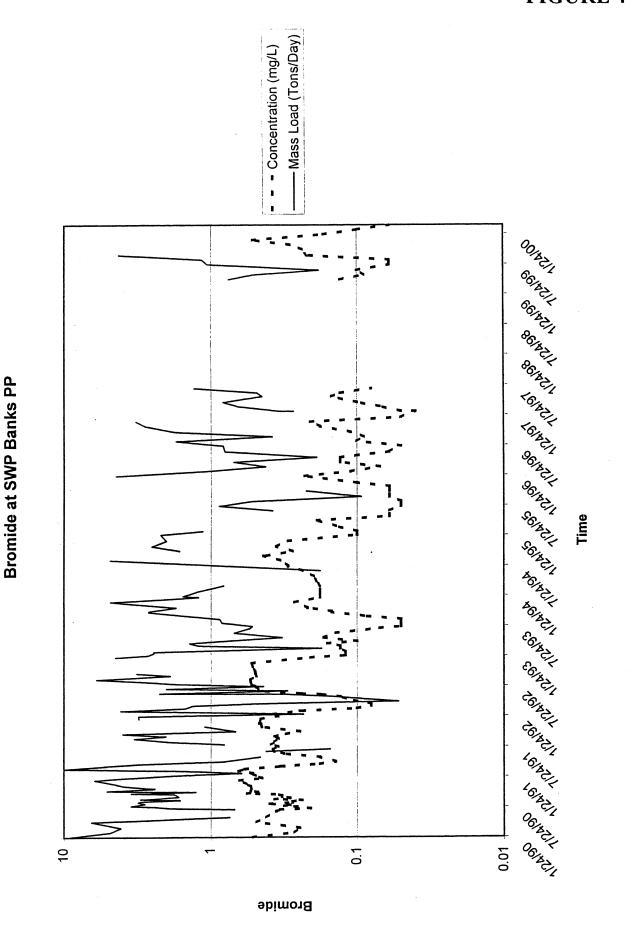


FIGURE 4-30



150

0.600

0.147

0.095

0.100

0.130

0.120

0.098

0.061

Month

0.065

0.102

0.137

0.194

■ Wet Years

□ Dry Years

☐ All Years ■ Wet Years

0.275

demonstrate the high reliance the current Delta configuration places on fresh water flow to repel seawater intrusion. During low flow conditions, the ability to repel saline water is reduced, thus resulting in higher bromide concentrations in drinking water supplies diverted from the Delta. Figure 4-33 indicates that March and January of dry years are particularly associated with high bromide loads in water diverted into the California Aqueduct. This is a reflection of the pattern of pumping into the aqueduct, and shows that the necessity to take water when it is available during dry years comes with a bromide penalty. Figure 4-34 and Figure 4-35 indicate the most frequently observed concentration and load ranges are 0.2 to 0.6 mg/L and 2 to 6 Tons/day, respectively.

Contra Costa Water District Pumping Plant #1

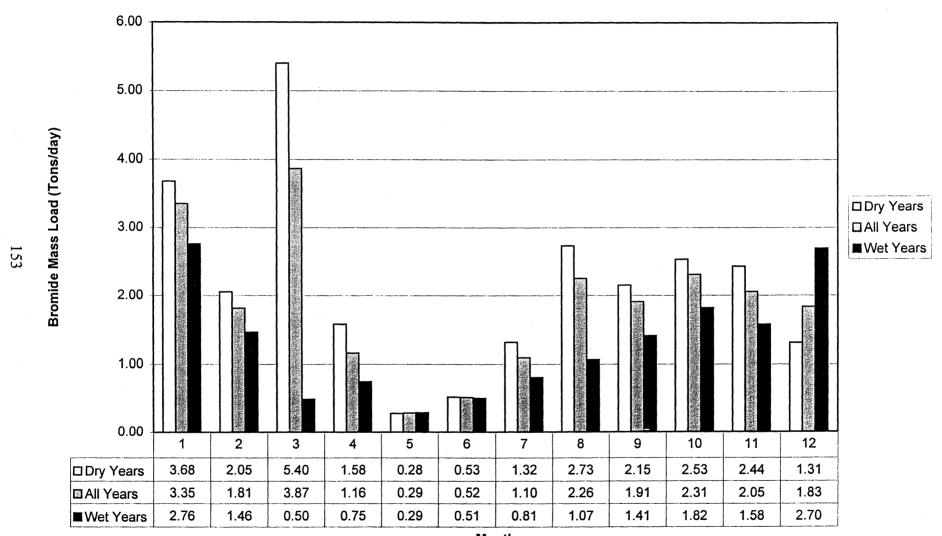
As shown in Figure 4-36, bromide concentrations at Pumping Plant #1, located at the end of Rock Slough, are quite variable, which is an indication of the relatively greater influence of sea water intrusion at this location, as compared to the SWP and DMC diversions further upstream (south) along Old River. Maxima generally occur during late fall. Figure 4-37 shows that, in dry years, concentrations at this location rise during the summer and fall months, reflecting low fresh water outflows and reduced ability to repel saline water in dry years. In wet years bromide concentrations tend to rise during the fall months, but begin rising later and to a lesser degree than in dry years. This is a clear indication of the importance of adequate salinity repulsion to the mineral quality of water available at Pumping Plant #1. Loadings, depicted in Figure 4-38, follow essentially the same pattern as concentrations.

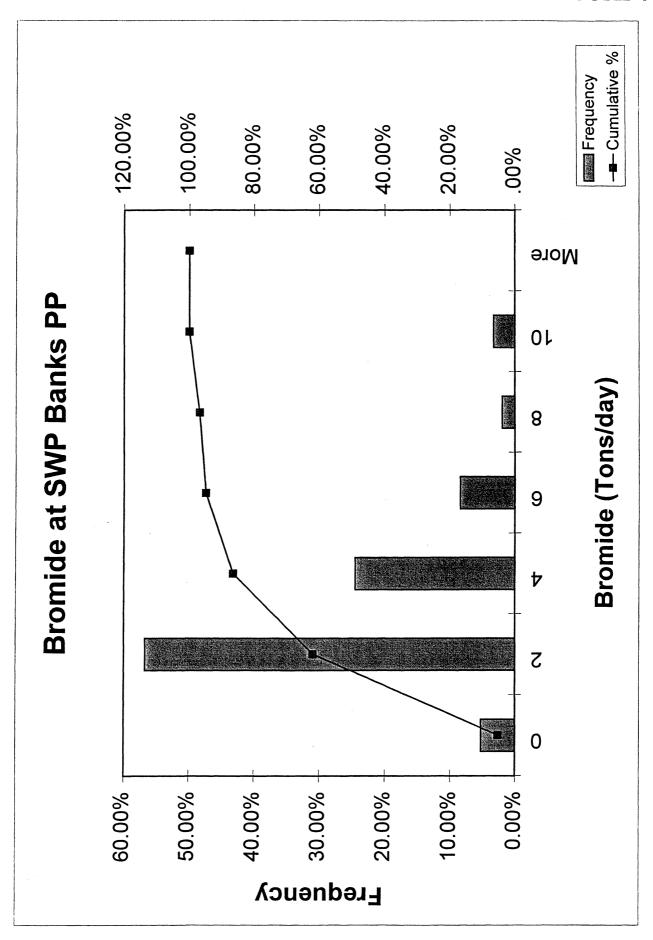
Figure 4-39 and Figure 4-40 show the most frequently observed concentrations and loads are in the ranges of 0.1 to 0.6 mg/L and 0.1 to 0.3 Tons/day, respectively.

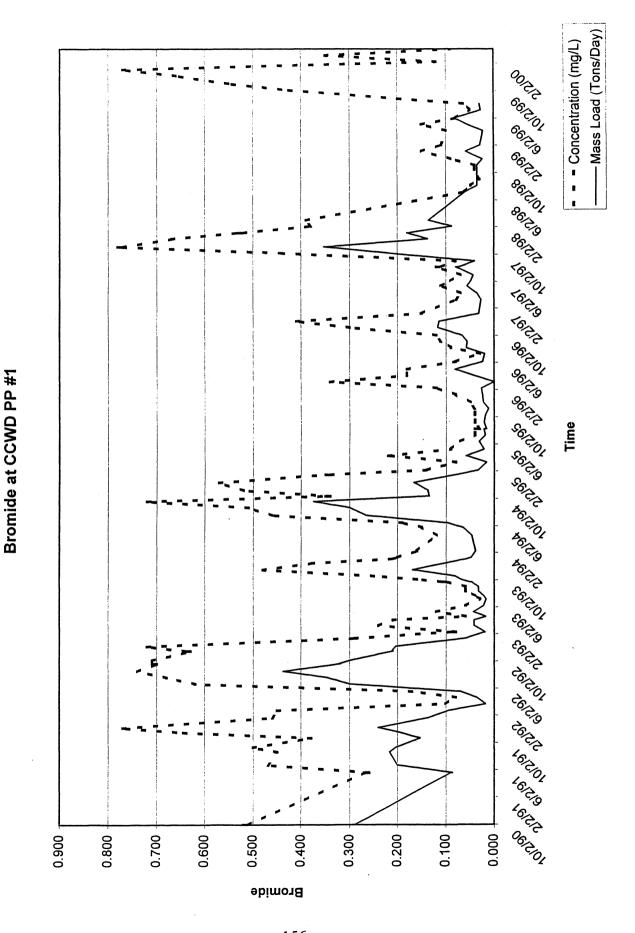
Delta Mendota Canal, Central Valley Project

Figure 4-41 depicts historical bromide conditions at the Delta Mendota Canal intake near Tracy Pumping Plant. The apparent trend of lower concentrations in later years is probably due to the predominantly dry earlier years and the predominantly wet later years in the period of record. As is seen at other locations, bromide concentration appears to be quite sensitive to flow, reflecting the importance of dilution capacity. Figure 4-42 supports this concept, as all months of dry years are associated with elevated bromide concentrations, whereas the opposite is the case for wet years. Figure 4-43 shows that the winter months are most important with respect to loads. Figure 4-44 shows the most frequently observed concentrations fall in the 0.100 to 0.600 mg/L range. Figure 4-45 shows most frequently observed loads are in the 0.4 to 4 Tons/day.

Bromide at SWP Banks PP

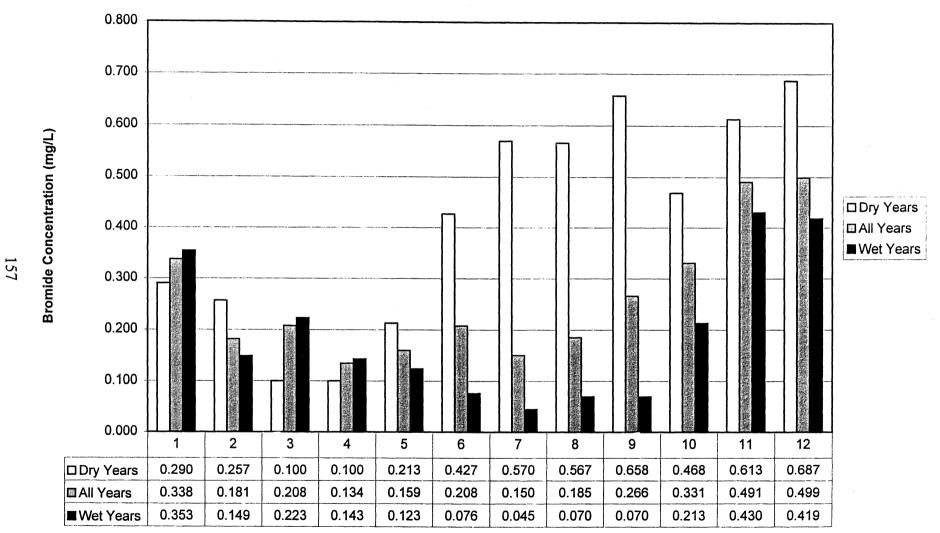




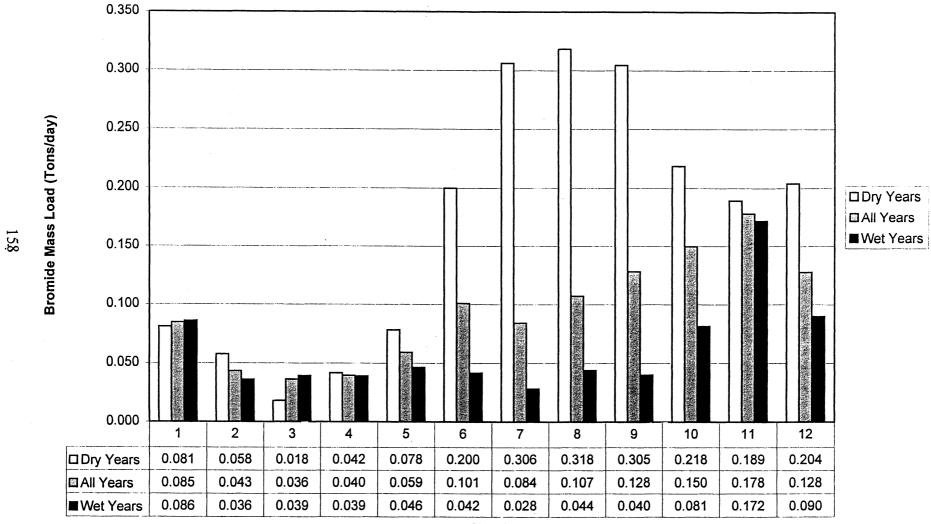


156

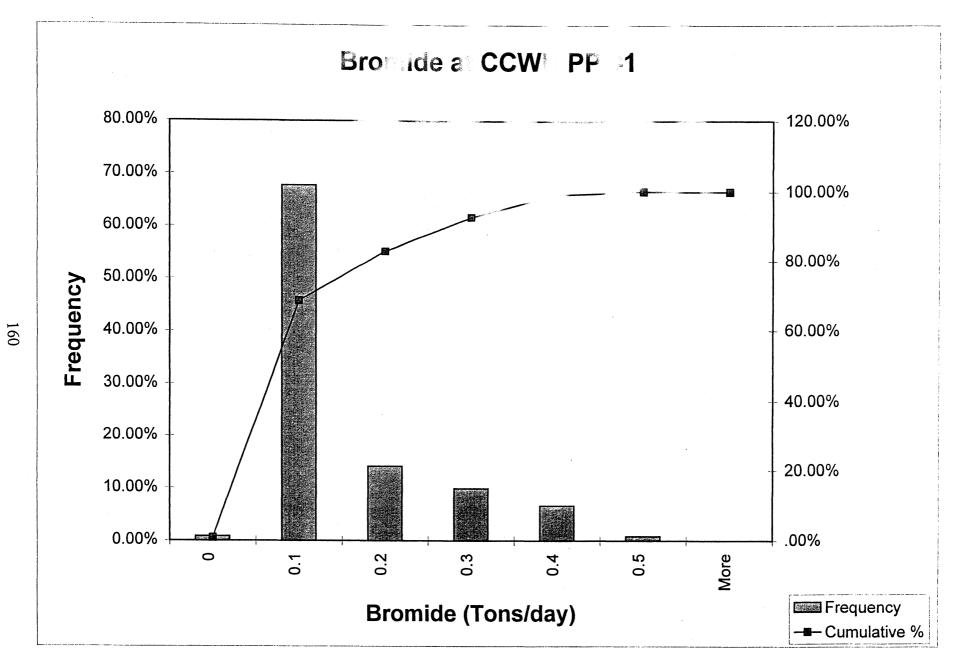
Bromide at CCWD PP #1



Bromide at CCWD PP #1



Bromide at CCWD PP #1



Bromide at DMC Intake

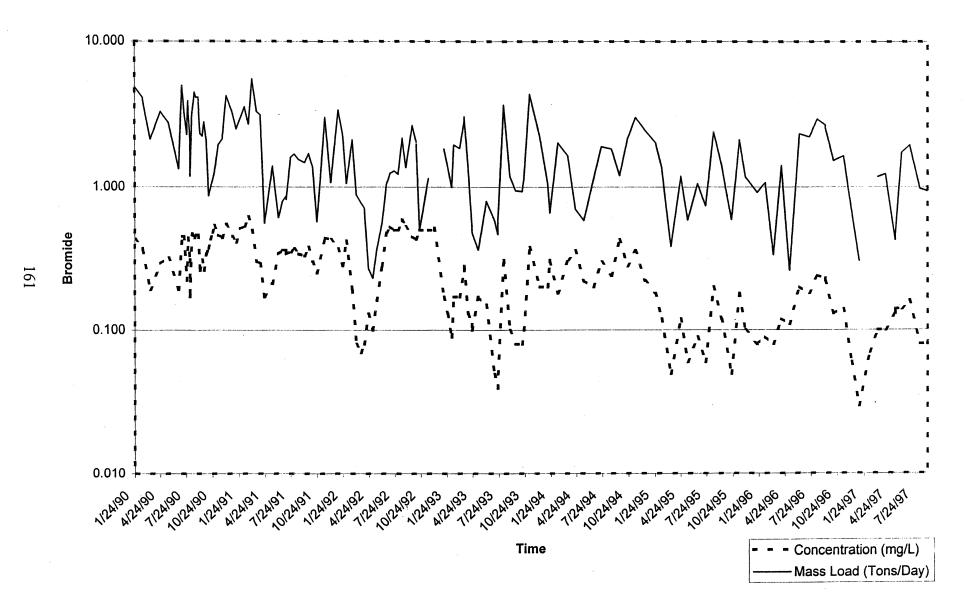
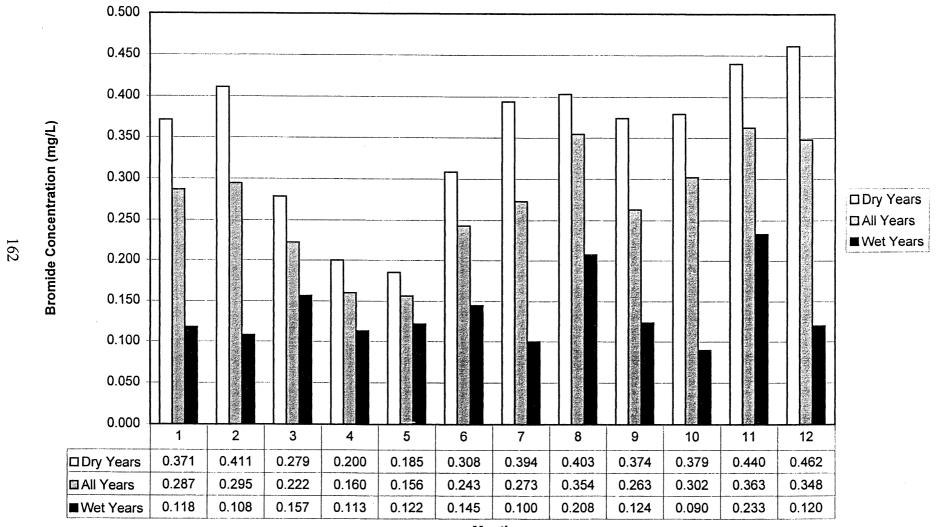
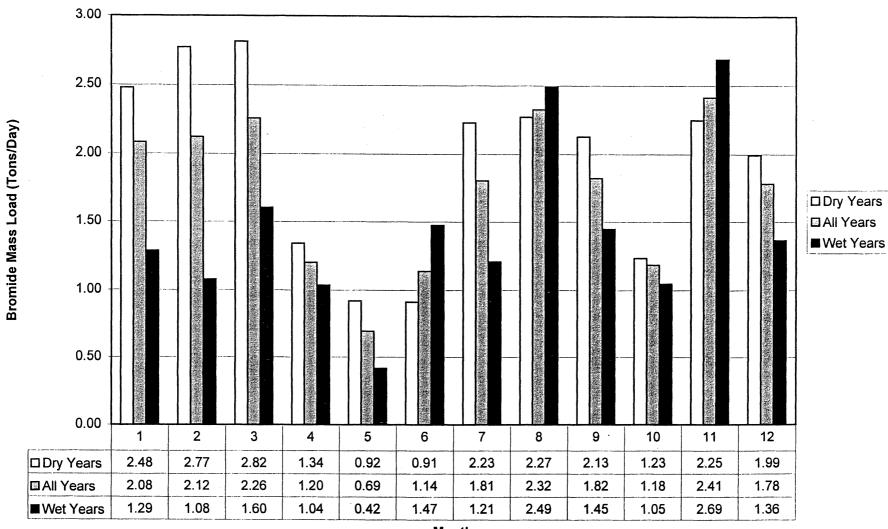
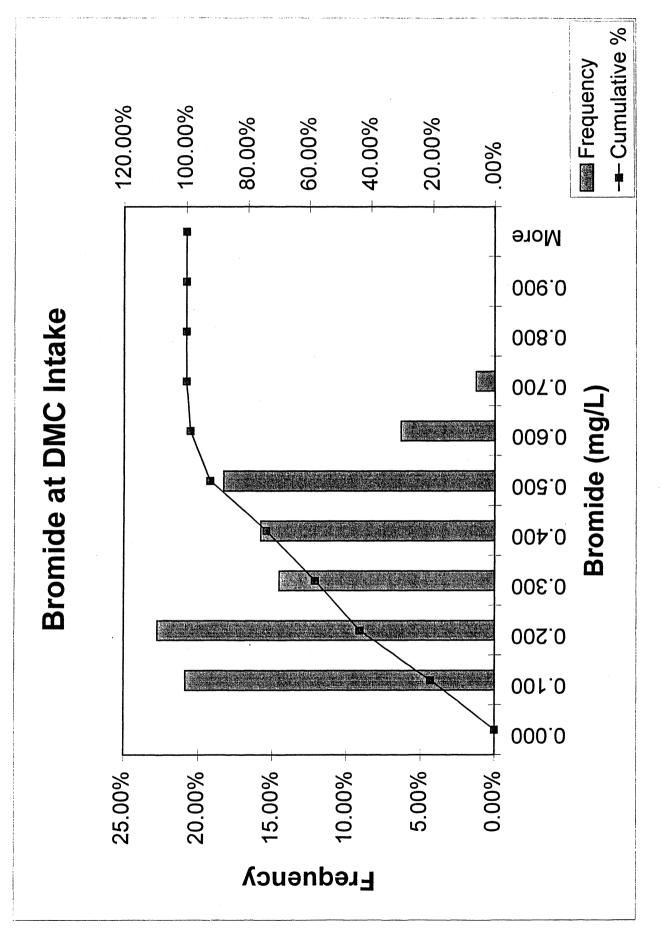


FIGURE 4-41

Bromide at DMC Intake







Ultra Violet Absorbance at 254 nm

Measurements of ultraviolet absorbance at a wavelength of 254 nanometers are believed to provide an indication of the presence of organic carbon that may react to form disinfection byproducts. This is, however, an indirect measurement, and can be subject to interference by certain aromatic organic chemicals. 6/

UVA data are collected by the Department of Water Resources and others, and are available for analysis. Figure 5-1 presents an areal depiction of UVA measurements at key Delta locations.

Consistent with higher organic carbon concentrations measured at the intake to the North Bay Aqueduct, UVA is also higher than in other drinking water diversions. Delta island drainage is associated with particularly high UVA measurements, indicating larger concentrations of organic carbon. UVA measured at drinking water diversions in the south Delta appear to reflect the influence of island drainage.

Specific Ultra Violet Absorbance, or SUVA, is calculated by dividing the UVA reading of a water sample by the concentration of total organic carbon in that sample, then by multiplying by 100. This calculation is believed to provide an indication of the qualitative makeup of the organic carbon molecules comprising the TOC. Water treatment processes are normally efficient at removing large organic complexes of humic and fulvic acids that result from decay of plant material. SUVA measurements above 2 are indicative of higher composition of these large molecules; therefore, SUVA readings above 2 provide an indication that the organic carbon being measured will tend to be efficiently removed in the treatment process. SUVA values below two, on the other hand, are indicative of the presence of smaller molecular weight and more difficult to remove organic carbon compounds. The overall SUVA status at key Delta locations is depicted in Figure 5-2. In general, it appears that total organic carbon in the Delta tends to be of the variety that is subject to good removal by treatment.

Delta Triburaries

UVA in the major fresh water inflows to the Delta is characterized below.

Sacramento River

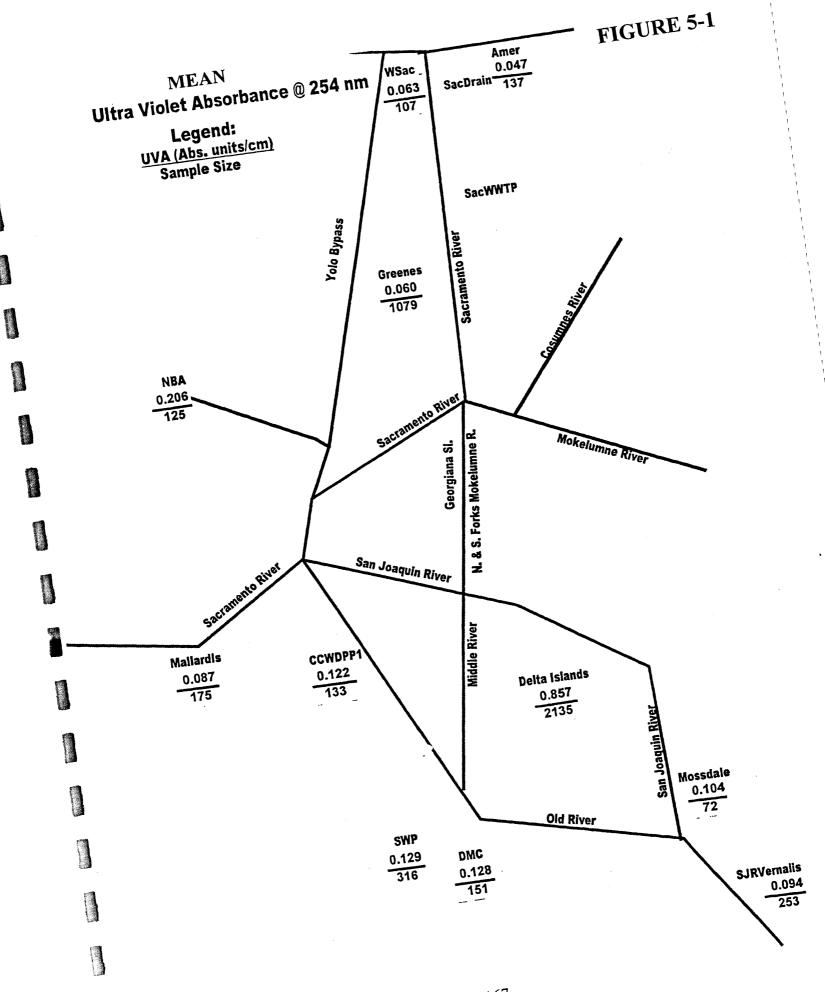
The order of discussion is from upstream to downstream

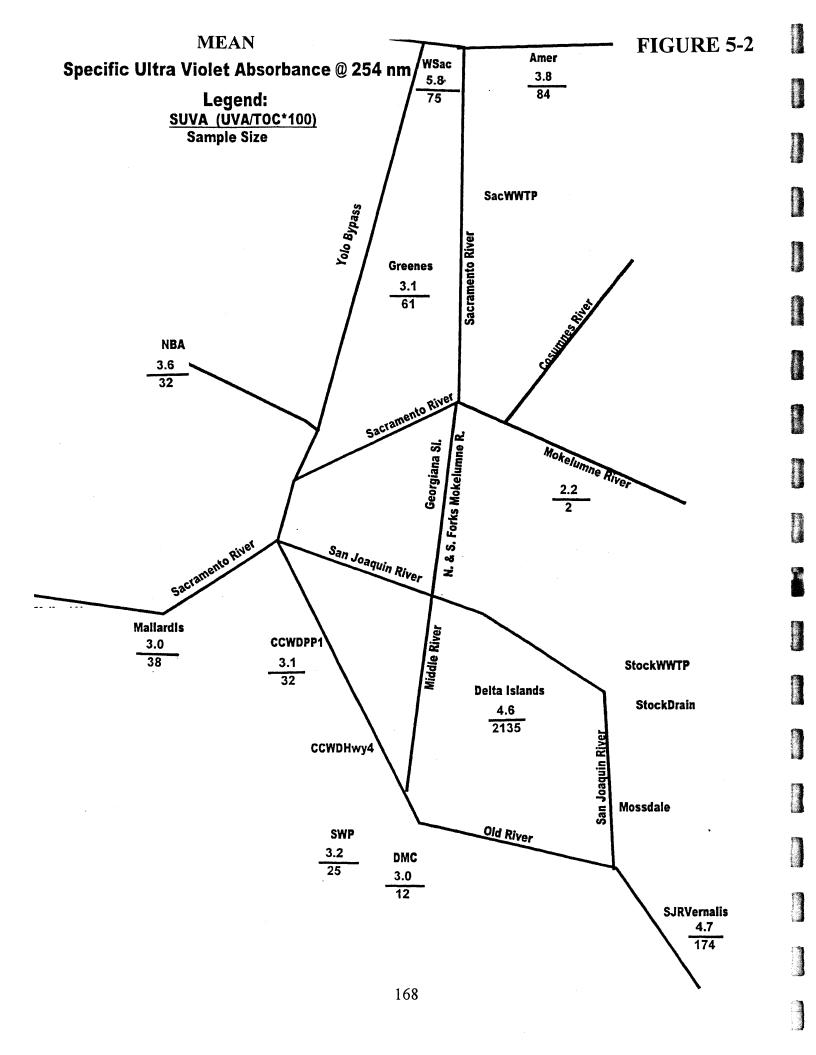
West Sacramento Intake

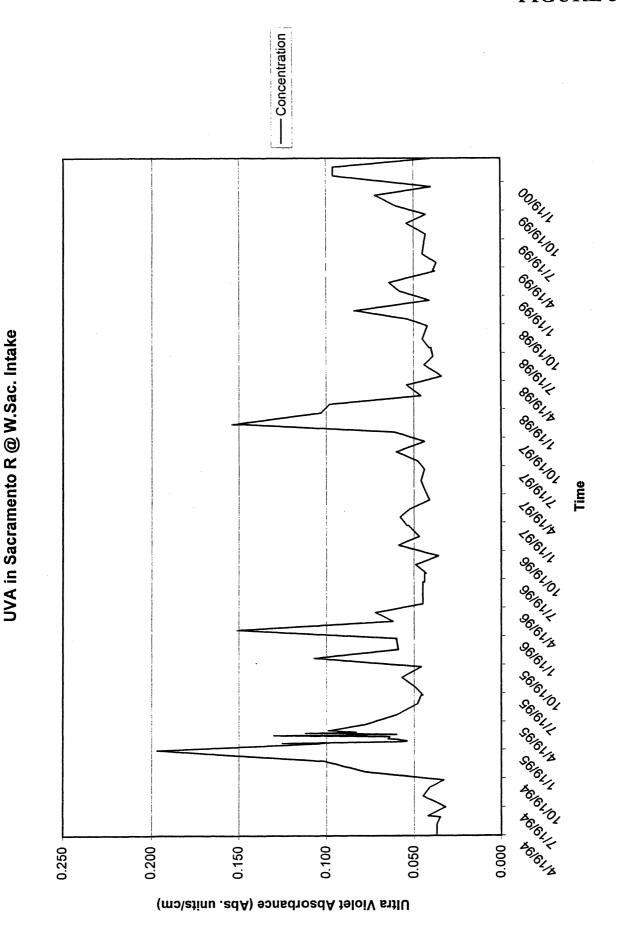
Figure 5-3 shows historical UVA readings taken at the intake to the West Sacramento water treatment plant. Peaks tend to occur during high flow conditions, consistent with organic carbon concentrations measured at the location. Most UVA measurements fall within the range of 0.040 to 0.100, with the majority falling within 0.060 and 0.080. Fiugre 5-4 shows monthly distributions of readings and Figure 5-5 shows the frequency distribution.

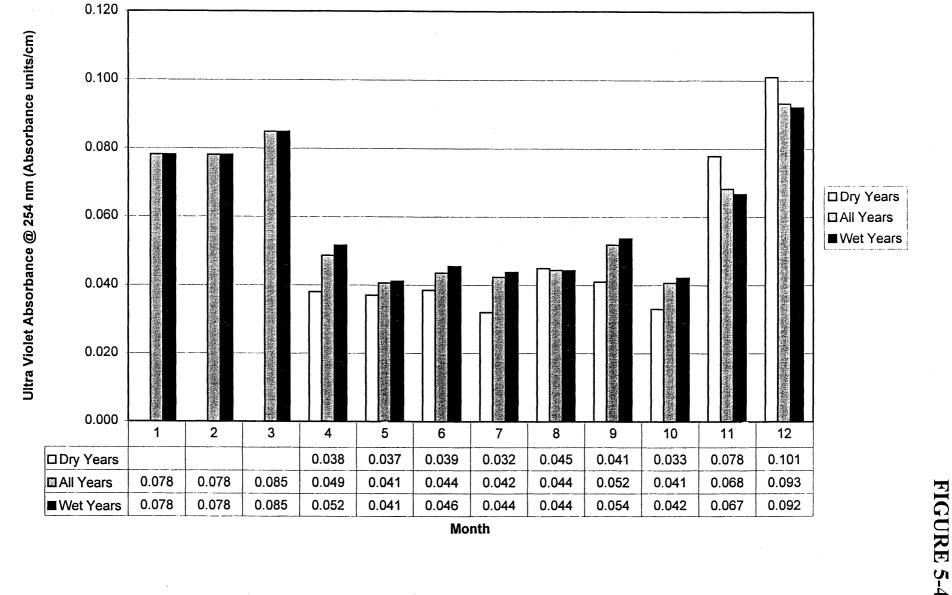
Greenes Landing

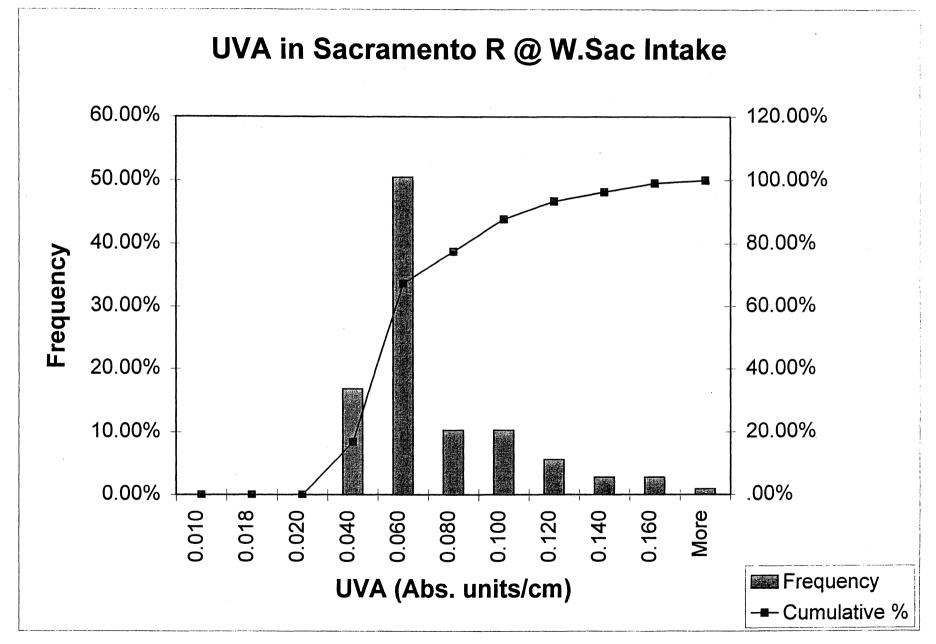
Historical UVA readings are summarized in Figure 5-6. Maxima have occurred during the months of December through March, typically when flows were high.

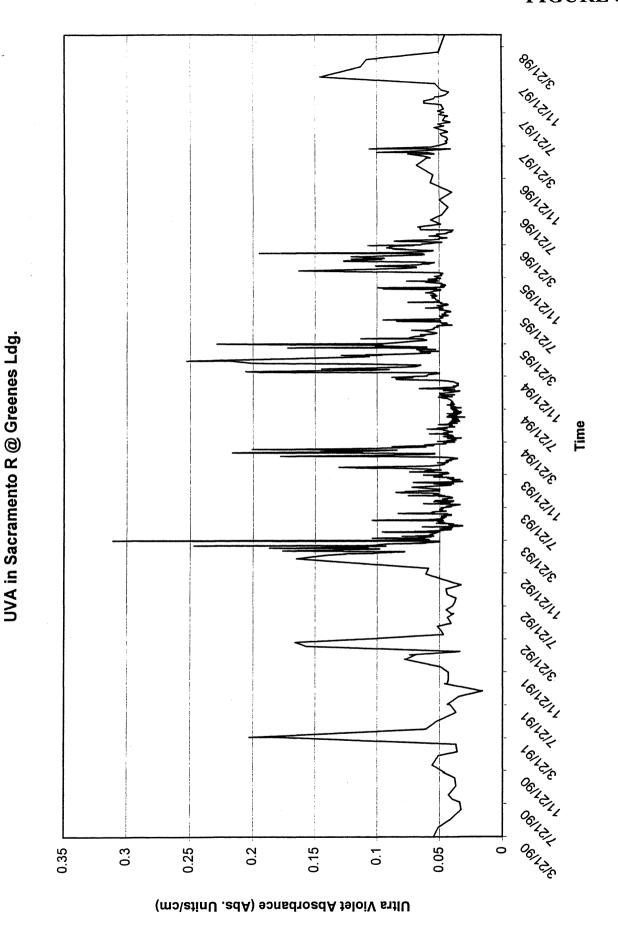












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Figure 5-7 demonstrates that wet months are associated with higher UVA readings. The most frequent UVA range observed is 0.050 to 0.150, as shown in Figure 5-8.

Mallard Island

UVA measurements since 1990 are summarized in Figure 5-9. Maxima were usually observed in the months of January through March, which is consistent with usual seasonal movement of organic carbon; however, the highest reading was observed in August of 1991, and is not explained. Figure 5-10 demonstrates that UVA maxima are associated with wet months, particularly January and February of wet years. The most frequently observed UVA readings lie in the 0.100 to 0.150 range, as is seen in Figure 5-11.

San Joaquin River

Historically, the San Joaquin River near Vernalis has been considered most representative of the San Joaquin River as it enters the Delta. The monitoring station there is generally upstream of major tidal influences.

Figure 5-12 shows historical UVA readings taken at the Vernalis sampling site. The record peak was measured in January 1993. Flow at the time was about 3900 cfs, which is not unusual. A DOC sample taken that day contained 11.4 mg/L, indicating the UVA reading probably reflected the DOC concentration spike that was observed at the time. January and February are associated with highest UVA readings, as depicted in Figure 5-13. According to Figure 5-14, most UVA measurements are within the range of 0.100 to 0.150 absorption units/cm.

American River

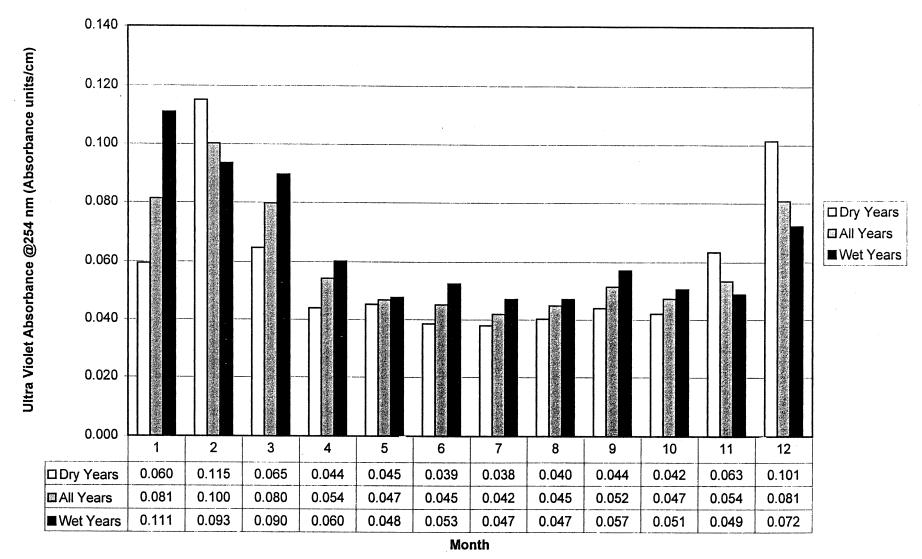
Figure 5-15 presents a historical summary of UVA readings taken in waters of the American River at the Sacramento water treatment plant. Maxima were observed in March 1991 and February 1992 during very low flow conditions prevalent in those critically dry years. Figure 5-16 shows the tendency for UVA readings to increase during the wet months, and reflects the high values that were recorded during 1991 and 1992. About 90 percent of UVA readings at this location are within the range of 0.025 to 0.100, as indicated by Figure 5-17.

Discharges

UVA data are presently unavailable for storm water and waste water discharges to the Delta, but data from Delta island drains have been acquired.

Delta Island Drainage

According to Figure 5-18, UVA readings in drainage from Delta islands tend to be high, probably reflecting the elevated concentrations of DOC that are observed. Fall and winter months appear to be most significant, perhaps reflecting discharges of winter leaching water and late summer and autumn discharges of irrigation returns.

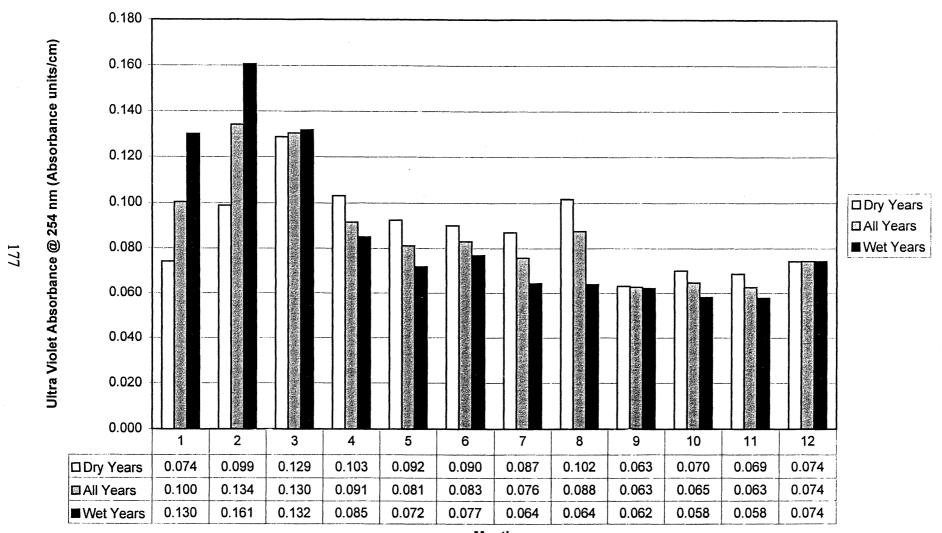


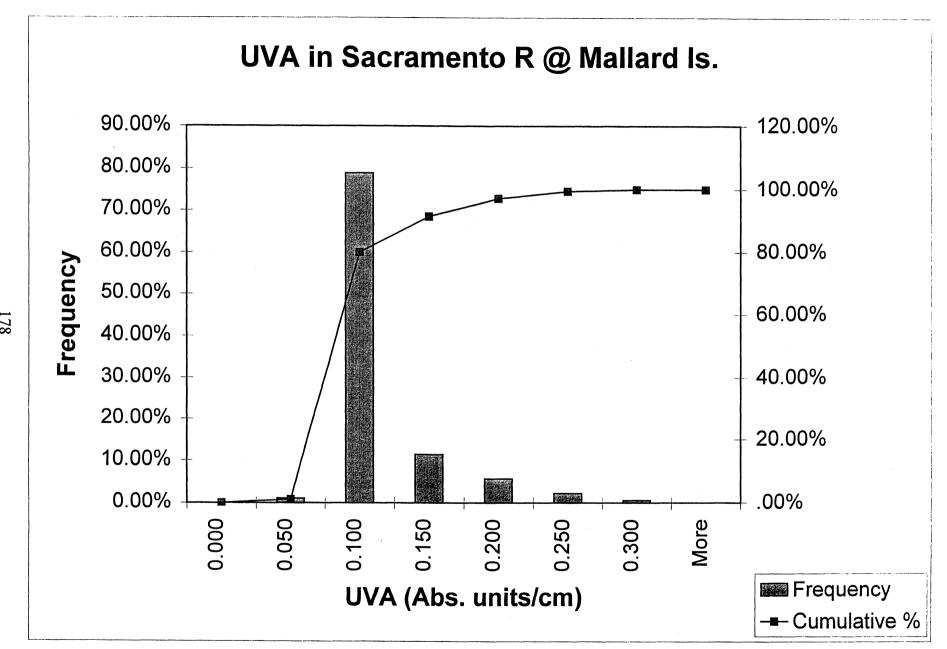
OOLES 66/12/11 66/12/1 66/4/6 10/12/1₁ 16/10/1 96/12/V *6/_{12/6} E6/12/1/ COVOL 66/19/6 JON J. C. 0.3 0.25 0.2 0.15 0.1 0.05 Ultra Violet Absorbance (Abs. units/cm)

UVA in Sacramento R @ Mallard Is.

176

UVA of Sacramento R @ Mallard Is

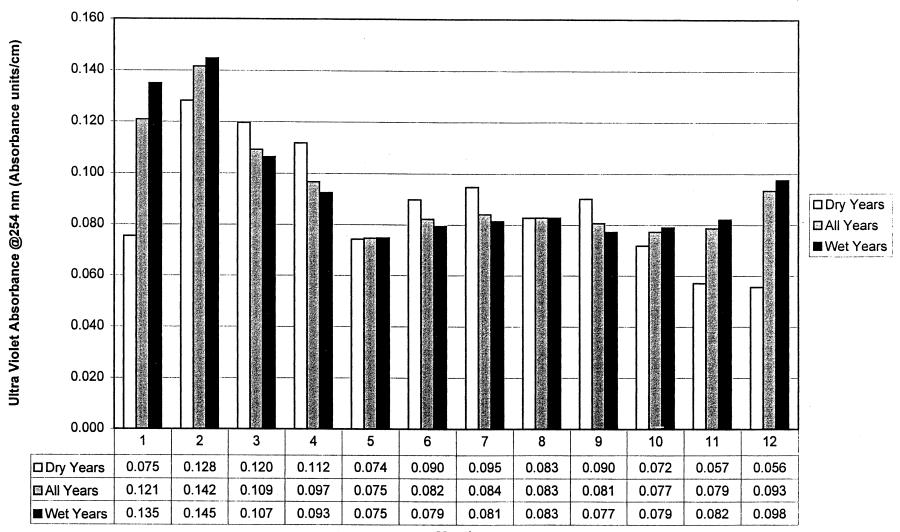


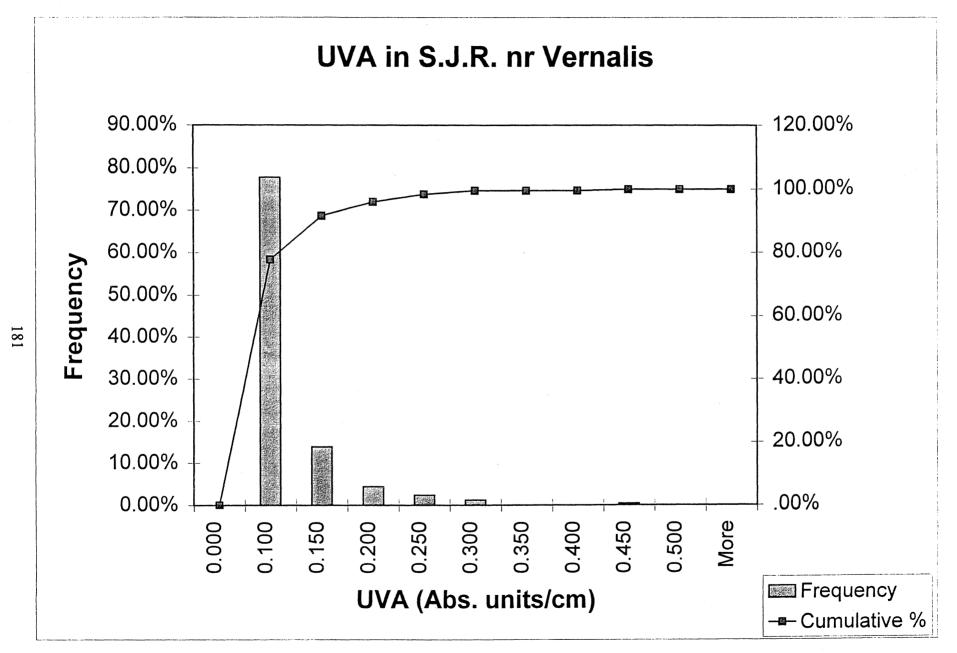


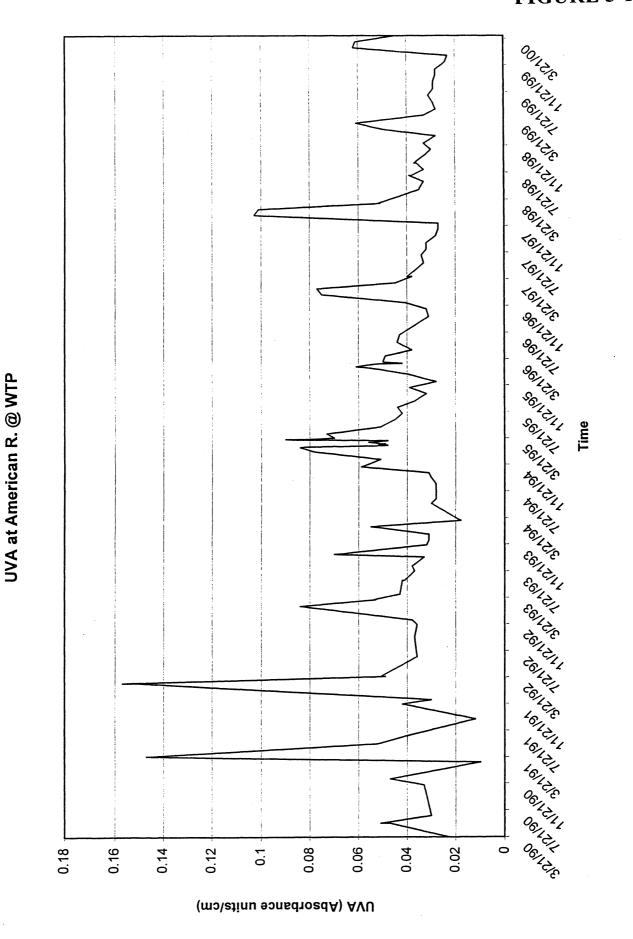
UVA in S.J.R. nr. Vernalis 0.5 0.15 0.05 0.45 0.35 0.3 0.25 0.2 0.4

Ultra Violet Absorbance (Abs. units/cm)

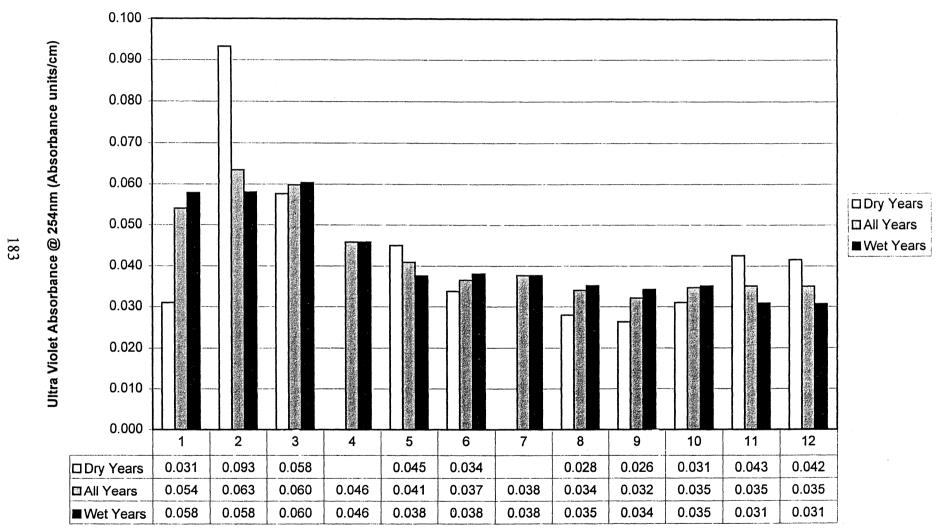
UVA in S.J.R. nr. Vernalis

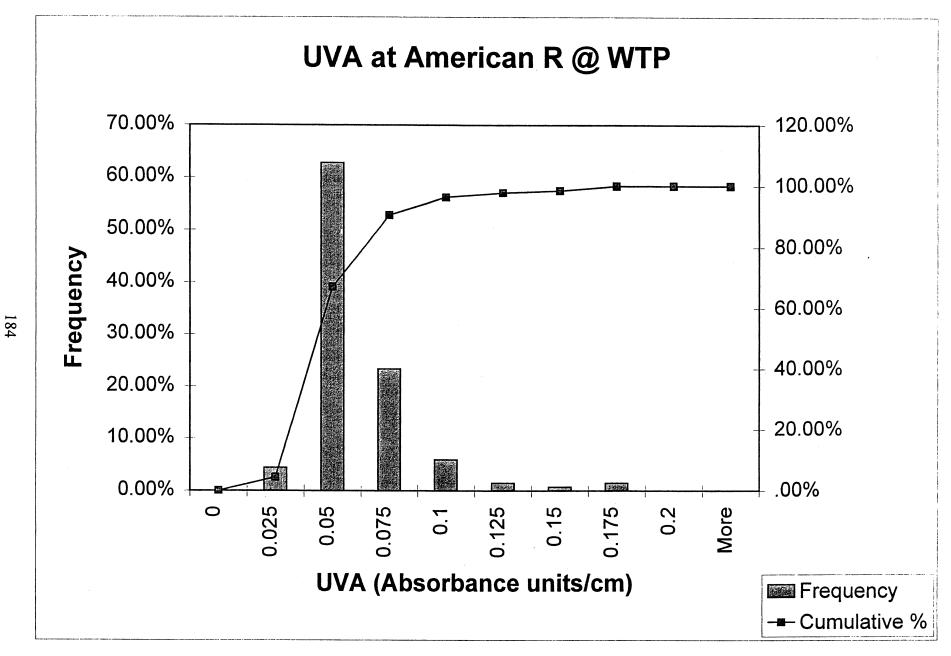


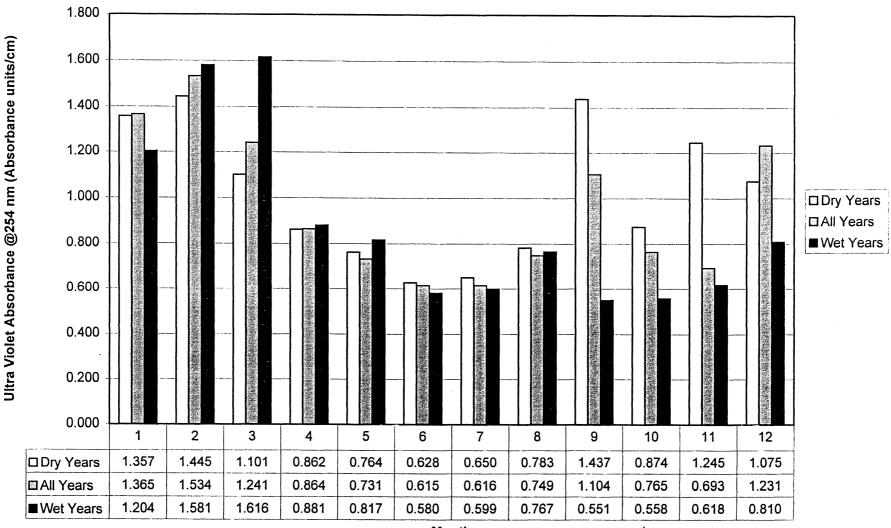




UVA at American R @ WTP







Diversions

The following is a discussion of UVA data representing the quality of the major drinking water diversions from the Delta.

North Bay Aqueduct, State Water Project

Figure 5-19 presents a summary of historical UVA readings taken from the intake to the North Bay Aqueduct. Maxima are observed in the months January through March. Referring to Figure 5-20, it can be seen that wet months, particularly during wet years, are associated with elevated UVA readings. These months are also associated with elevated concentrations of DOC at that location. Figure 5-21 shows that about 80% of UVA observations fall within a 0.100 to 0.300 range.

California Aqueduct, State Water Project

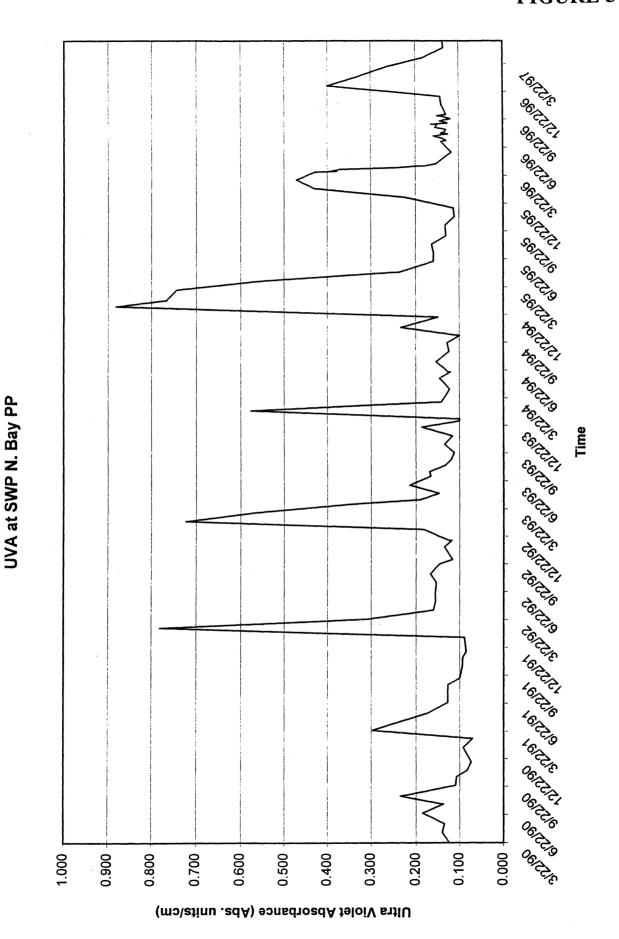
Historical UVA readings at H.O. Banks Pumping Plant are summarized in Figure 5-22. Maxima are generally found in the months of January and February. Monthly averages, depicted in Figure 5-23 show the months of January, February and March as being associated with higher UVA readings. This is consistent with the finding that DOC concentrations follow as similar pattern at this location. About 80 percent of UVA readings fall within 0.100 and 0.200 absorption units/cm, as indicated by Figure 5-24.

Contra Costa Water District Pumping Plant #1

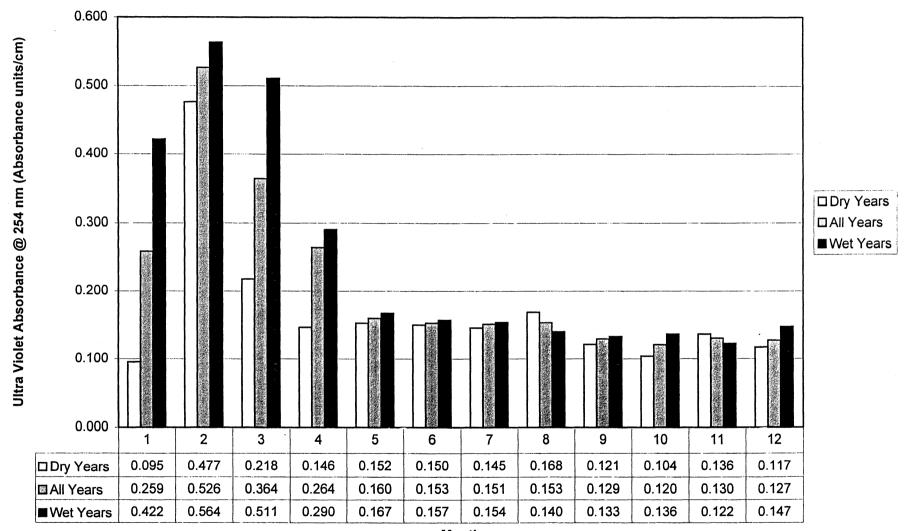
Figure 5-25 depicts historical UVA records for Pumping Plant #1. Maxima have been experienced during the months of January through March, as shown in Figure 5-26. Similar to the pattern exhibited at Banks Pumping Plant, wet months are associated with elevated UVA readings, and with increased DOC concentrations during these months. Figure 5-27 demonstrates that about 80 percent of UVA readings from this location fall within the 0.100 to 0.200 range, similar to Banks PP.

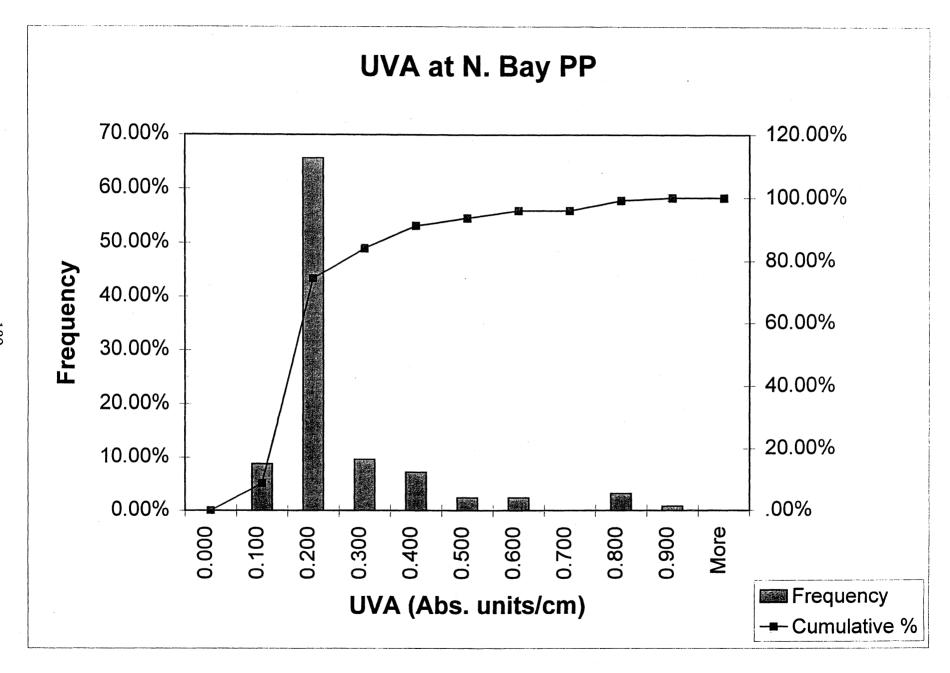
Delta Mendota Canal, Central Valley Project

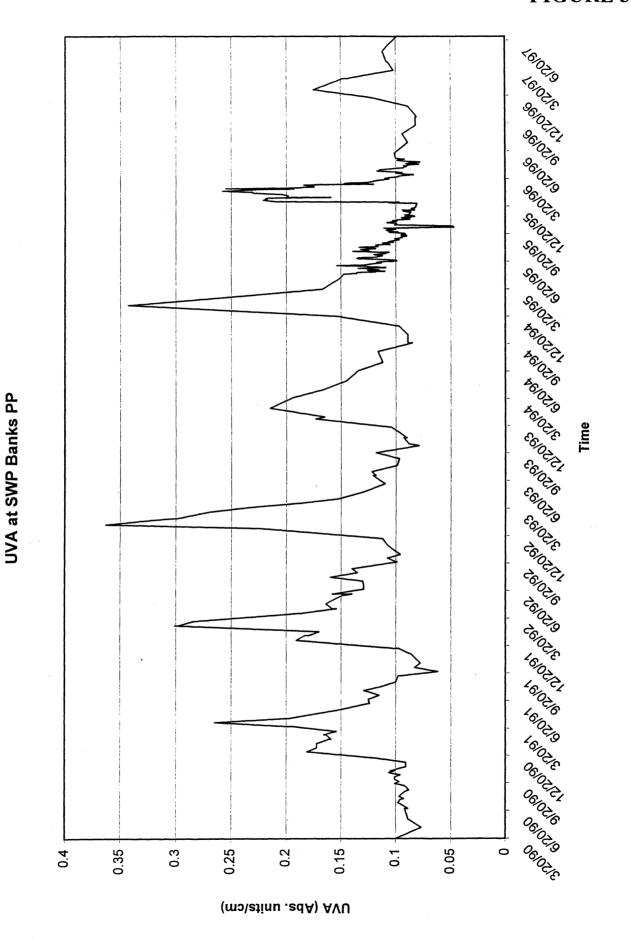
UVA data representing historical conditions at the intake to the Delta Mendota Canal appear in Figure 5-28. No long term trends of change are apparent. As is the case at Banks Pumping Plant and Contra Costa Water District Pumping Plant #1, maxima are observed during the months of January through March and are associated with elevated DOC concentrations at those times (Figure 5-29). As depicted in Figure 5-30, most commonly observed UVA readings fall in the 0.100 to 0.200 range.

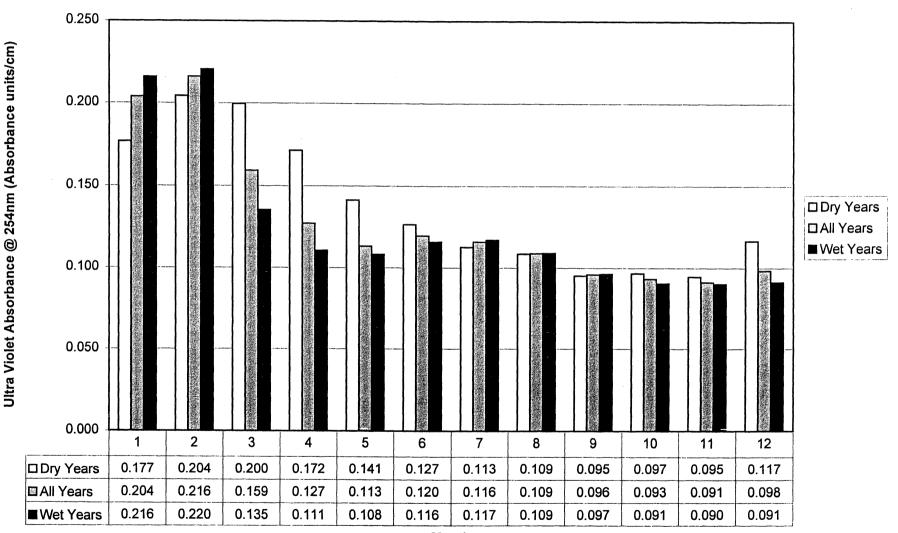


UVA at SWP North Bay PP









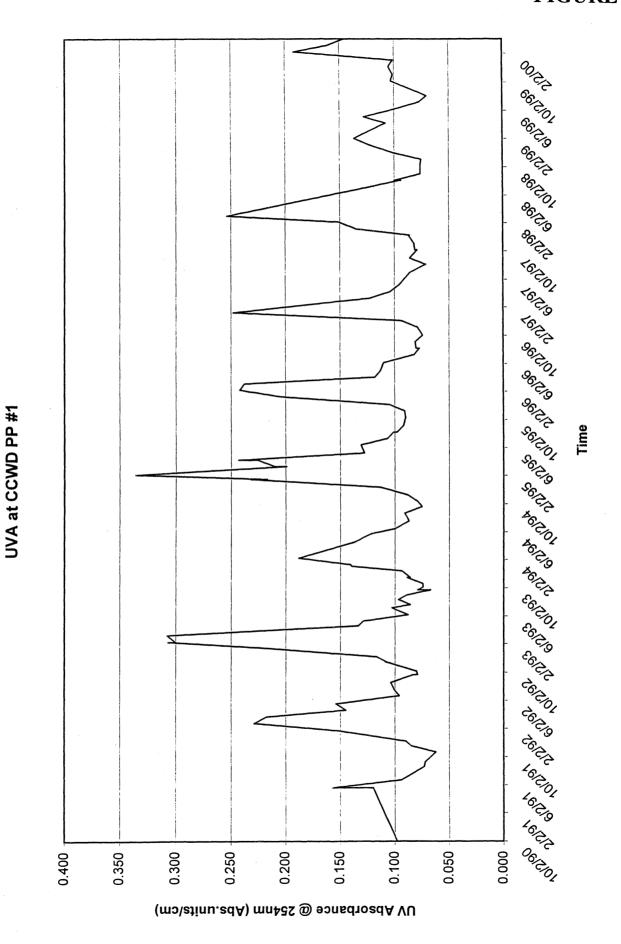
Month

FIGURE 5-23

UVA at SWP Banks PP

45.00%

120.00%



0.096

0.087

0.080

0.081

0.086

0.098

0.105

0.120

194

0.250

0.200

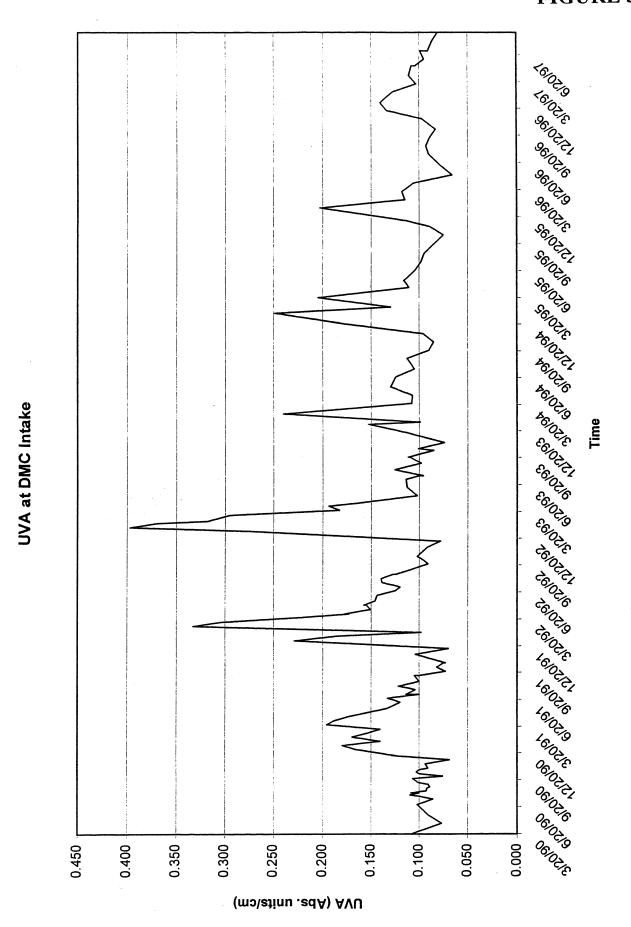
■Wet Years

0.179

0.238

0.213

0.160



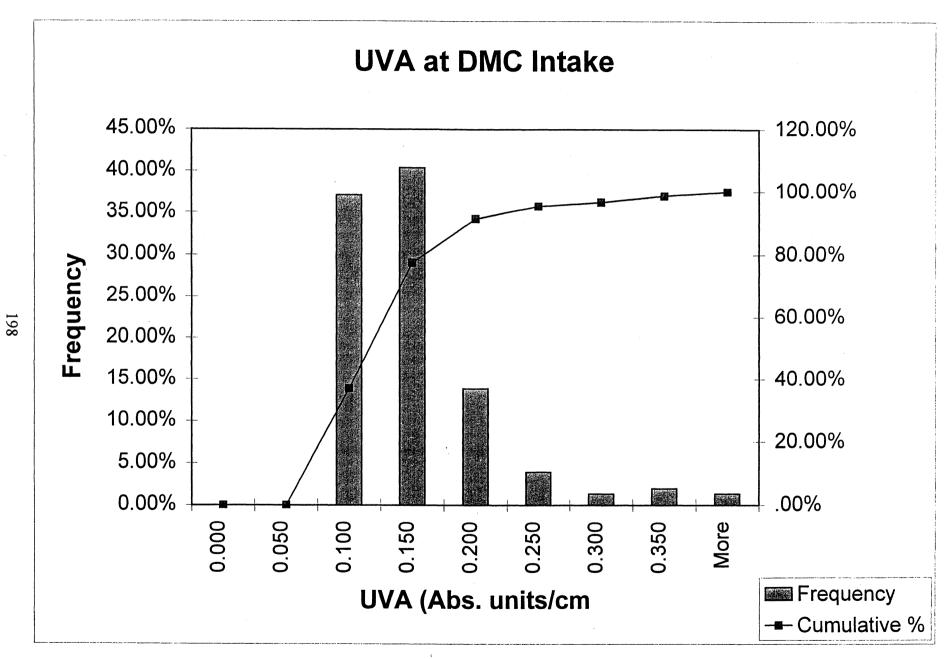
196

0.300

□ Dry Years

☐ All Years

■ Wet Years



Salinity

Description

Among all constituents affecting the usability of water supplies, salt probably has the greatest overall effect. In high concentrations, dissolved minerals can cause taste and odor in drinking water, corrode municipal water facilities and homeowners' pipes and appliances, and can be unhealthy for susceptible individuals. Also, the CALFED program calls for significantly increased water recycling and reuse in order to stretch scarce supplies; the saltiness of water supplies will directly affect the ability to meet CALFED's goals in this area. Several minerals contribute to the saltiness of water. A useful measure of salt content is Total Dissolved Solids (TDS). In this test, a water sample is evaporated and the mineral residue is weighed, producing a measure of essentially all dissolved minerals contained in the water. For this study, TDS was chosen as the preferred measure of salt content. TDS concentration is usually expressed in units of mass per unit volume (milligrams per liter or mg/L), and is the unit of measure used here.

Another measure of salt content is specific conductance, more popularly known as electrical conductance or EC, which is an inverse measure of the resistance of a water sample to passage of electrical current. This method relies on the fact that increasing mineral concentrations proportionately increase the electrical conductance of water, yielding increased EC. In most Delta waters there is a strong relationship between EC and TDS. A general formula for estimating TDS is: TDS = EC * 0.6 To evaluate the applicability of this formula for estimating TDS in Delta waters, a regression analysis was performed on about 6200 measurements of EC and TDS made on fresh waters in Delta channels. The R Square for the above equation was 0.99, indicating the formula is generally adequate. Specific predictive equations were derived for predicting TDS from EC values at specific locations.

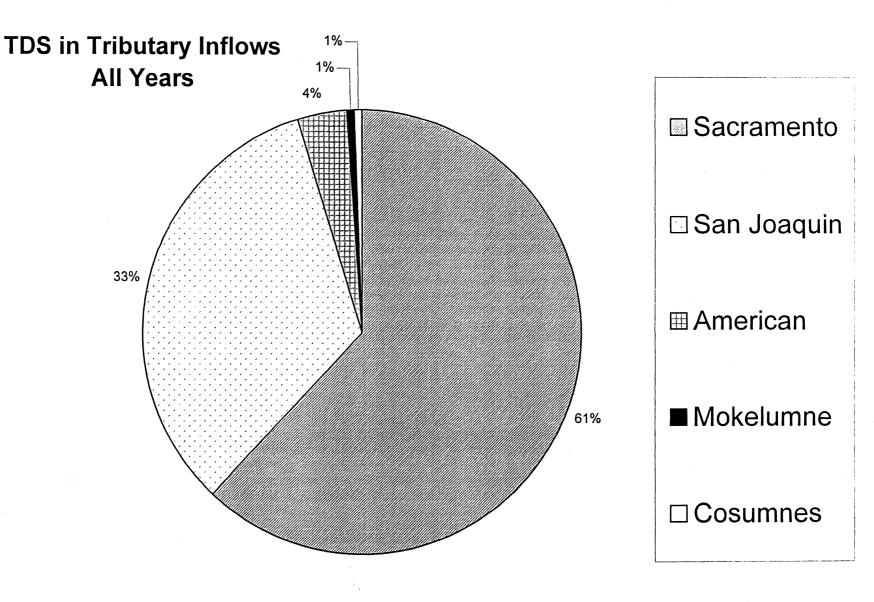
In order to enable EC data to be used along with TDS data derived by laboratory analysis, regression analyses were performed to derive individual predictive equations for key locations in the Delta. Estimation of TDS by use of EC data has been particularly useful at locations where continuous recorders are installed. Data summaries using a large amount of calculated TDS data from continuous recorders produced similar, but better refined, estimates than discrete samples for TDS at the San Joaquin River near Vernalis and Delta Mendota Canal Headworks locations. Also, TDS data were sometimes predicted from EC data where no TDS samples were analyzed.

Total Dissolved Solids

The following section discusses baseline salt conditions in waters tributary to, and diverted from, the Sacramento-San Joaquin Delta, as characterized by total dissolved solids (TDS).

Figure 6-1 demonstrates the overall contributions of TDS mass load from the streams influent to the Delta. Even though the Sacramento River is relatively low in TDS (about 100 mg/L average), the relatively large proportion of Sacramento River Flow results in





the salt load from this stream being by far the largest, at nearly two-thirds of total tributary inflow. The San Joaquin River is next largest, comprising about one-third. The remainder of the tributaries to the Delta are not very significant, together comprising about six percent of the total.

Figure 6-2 depicts overall concentrations and loads of TDS from inflows to, and diversions from, the Delta. Clearly, the Sacramento River overwhelms other sources, while the San Joaquin River is also significant. Although San Joaquin River flows are considerably lower than is the case for the Sacramento River, the TDS of San Joaquin River water averages seven times that of Sacramento River water, thus accounting for the relatively high mass load from this source.

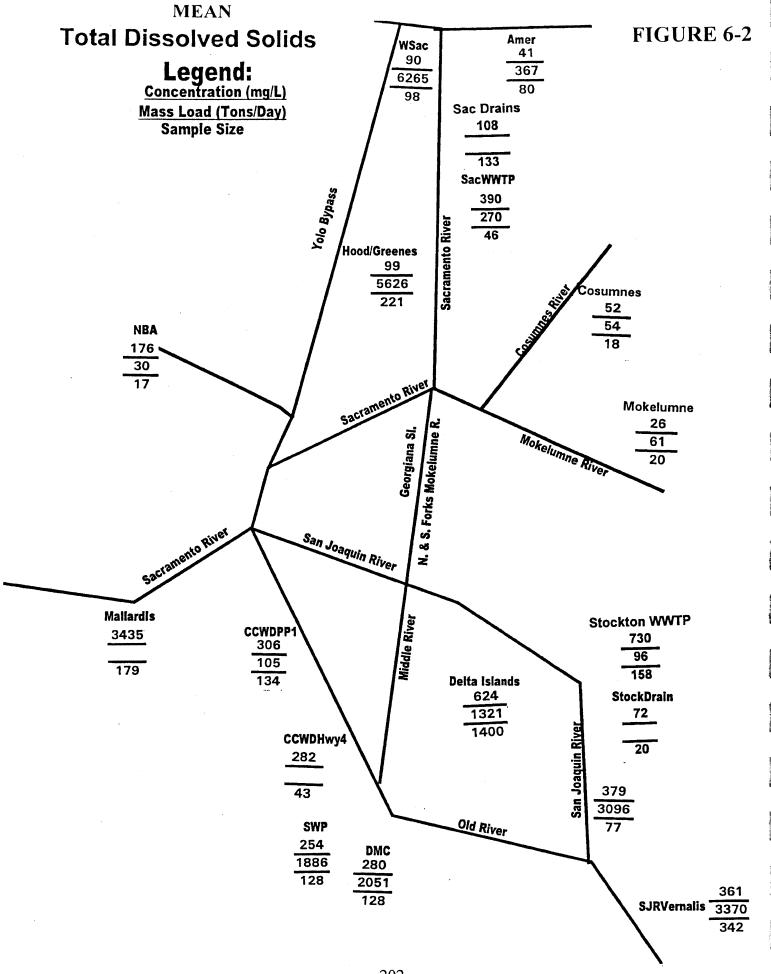
The salt load flowing into the State Water Project and Federal Delta Mendota Canal is primarily derived from the Sacramento and San Joaquin Rivers; however because of the flow pattern that causes San Joaquin River water to flow to the diversion pumps, the influence of the San Joaquin River is disproportionately large at these southern Delta diversion locations. Because the DMC takes water more or less continuously from the Old River channel, the influence of the San Joaquin River on that diversion is especially pronounced during lower flow conditions when the volume pumped through the DMC can equal or exceed the flow in the San Joaquin River.

The effects of taking State Water Project supplies through Clifton Court reflects the increased proportion of Sacramento River water that is taken into the SWP as a result of opening the Clifton Court gates during high tides when the influence of the Sacramento River is maximized. The result is water having averaging about 10 percent lower in TDS concentration and about 9 percent lower in TDS load than is found in DMC diversions.

Although TDS concentrations in Delta island drainage are similar overall to those seen in the San Joaquin River, while mass loadings are about 40 percent of the San Joaquin River loading, reflecting the smaller quantity of island discharges. However, because a number of island drains are in the near vicinity of the diversion locations, this drainage has a disproportionately large influence on the quality of water diverted through the State and Federal facilities, and through the facilities of Contra Costa Water District.

The mean TDS concentration at Contra Costa Water District's intake on Rock Slough is about 17 percent higher than is found at the SWP intake facility further upstream on Old River. This reflects the influence of sea water instrusion that affects the Rock Slough intake more than is the case for the SWP and CVP intakes. The mean TDS at CCWD's new intake on Old River at Highway 4 lies between that at Rock Slough and the SWP intake, reflecting progressively lessening sea water intrusion as one looks upstream.

The North Bay Pumping Plant Intake on Barker Slough is characterized by relatively low TDS concentrations and minor loads, owing to its being influenced by the Sacramento River, its being less affected by sea water intrusion, and the comparatively small volume of this diversion as it affects the load calculation.



Because the American, Mokelumne, and Cosumnes Rivers have low mineral content and relatively low flows, their impacts on Delta water quality will not be evaluated in detail in this study. Detailed evaluations will, however, be conducted for the Sacramento and San Joaquin Rivers.

Delta Tributaries

Total dissolved solids in the major fresh water inflows to the Delta are characterized in this section.

Sacramento River

As the largest fresh water inflow to the Delta system, the Sacramento River has a pronounced effect on the salinity of water supplies taken from the Delta.

Upstream Sacramento River

Data for most water quality parameters of interest were found to be lacking for the Sacramento River upstream of Verona. Some specific conductance (EC) data are, however, available for analysis. Figure 6-3 displays a summary of EC data collected from various locations along the Sacramento River from upstream of Lake Shasta to below Knight's Landing. One can observe a slow rise from less than 120 uS/cm (equivalent to about 70 mg/L TDS) to about 150 uS/cm (~90 mg/L TDS) as the river flows to a point above the discharge of the Colusa Basin Main Drain at Knight's Landing. This increase and the others observed further downstream are probably due in large part to irrigation water returns to the river along its course between Redding and Sacramento. The EC of the river increases about 35 uS/cm (~20 mg/L TDS) reflecting the influence of the Colusa Basin Main Drain discharge. The Feather River confluence with the Sacramento is just upstream of Verona, so the EC of the water at Verona falls about 60 uS/cm (~35 mg/L TDS) reflecting the beneficial dilution effects of the Feather River. By the time the water has moved to below Knight's Landing, it has again increased in salt content, probably reflecting other agricultural drainage into the system.

West Sacramento Intake

Figure 6-4 shows historical TDS concentrations and loadings, which appear not to be undergoing long term change. Concentrations remain relatively constant, at about 100 mg/L, so changes in mass loading will be due primarily to flow changes. Figure 6-5 depicts average monthly TDS under different hydrologic conditions, and shows only modest TDS concentrations increases associated with drier years. Loadings as depicted in Figure 6-6 present a different pattern, with wet months producing loads as much as four times higher than during drier months. Figure 6-7 indicates that the predominance of TDS measurements fall in the range of 100 to 150 mg/L; Figure 6-8 shows that the most common TDS mass load is between 6,000 and 8,000 Tons/day.

Greenes Landing

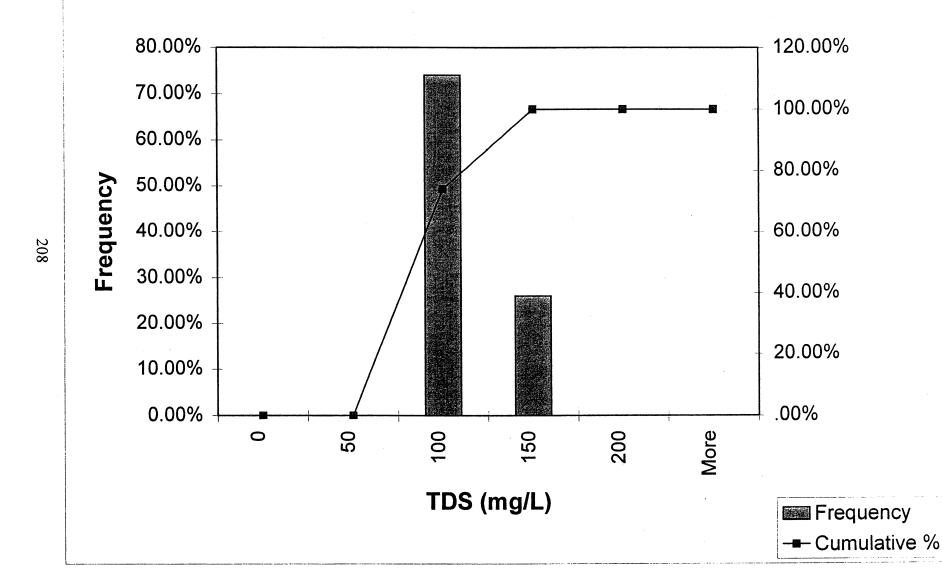
Figure 6-9 summarizes TDS concentrations and loads in the Sacramento River at Greenes Landing, which also reflects the influence of the American River. During the period of available record, TDS concentrations and loadings appear to have remained relatively stable, with the exception that loadings in the years since 1995 have been elevated, reflecting the fact that these years are classified as wet and are, therefore, associated with

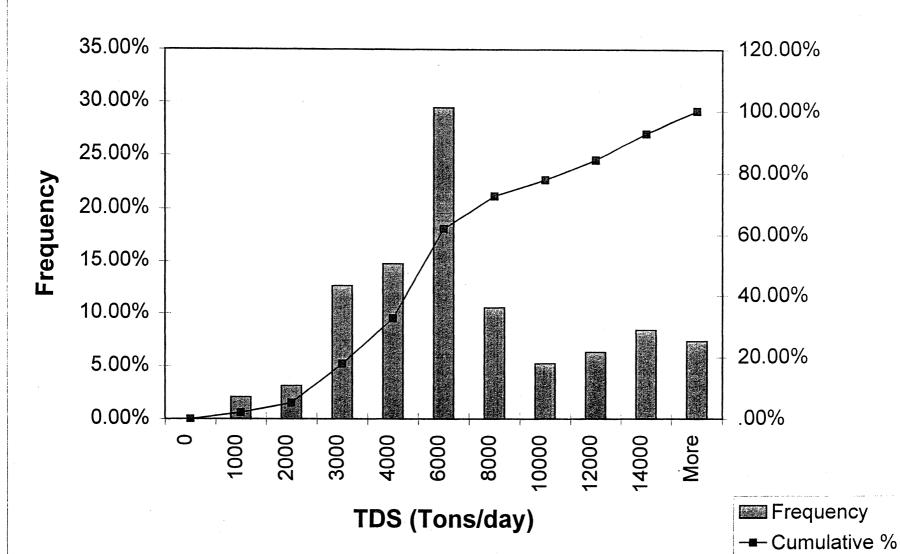
Location (upstream to downstream)

■ Wet Years

Month

FIGURE 6-5





higher flow. The apparent TDS spike (374 mg/L) that occurred in September 1997 is not explained, but may reflect upstream agricultural drainage that is typically discharged in the fall.

Figure 6-10 shows mean monthly TDS concentrations in the Sacramento River at Greeenes Landing for all years taken together; for below normal, dry, and critical years (called Dry Years on the figure); and, for above normal and wet years (called Wet Years on the figure). Dry years are generally characterized by higher TDS concentrations in most months, as compared to all years taken together. The converse is generally true for wet years. This observation is consistent with the concept that low Sacramento River flows will generally tend to reduce salt dilution while higher flows will generally increase dilution. Interestingly, Septembers appear to be atypical, with wet year TDS concentrations being higher and dry years being lower in TDS concentrations. The unusually high TDS concentration (374 mg/L) observed in a sample collected on September 3, 1997, would reduce the average wet year September TDS to 101 mg/L if this value were eliminated from the calculation, suggesting the need to investigate the validity of this result and, if accurate, to further investigate possible causes.

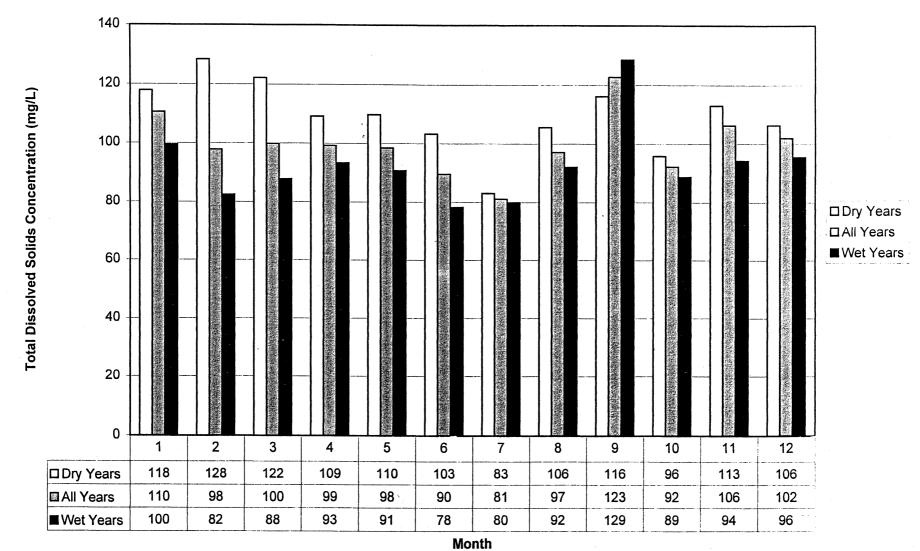
Figure 6-11 depicts mean monthly TDS loadings at the same location. Loadings generally increase as flows increase, as reflected in the differences among hydrologic conditions, and this pattern appears to exist for essentially all months. The wetter months January through March also demonstrate pronounced loading increases, reflecting higher flows. If one hypothesized the existence of a fixed quantity of salt available for annual dissolution in the watershed, one would expect to see loadings remain constant while concentrations decreased with increasing flow. Observation of increasing loads with increasing flows suggests that higher flows are more rigorous in dissolving salts than is the case with lower flows. This observation is consistent with the idea that increased flow velocities associated with wet conditions may result in more rigorous salt dissolution, and such an explanation seems plausible. Another hypothesis might be that there are salt sources under human control that are preferentially discharged during wet conditions. This hypothesis would seem to lack merit, as discharge of salt "slugs" in a quantity sufficient to affect TDS loadings in the watershed would be expected to be observed as major spikes, which generally appear to be absent.

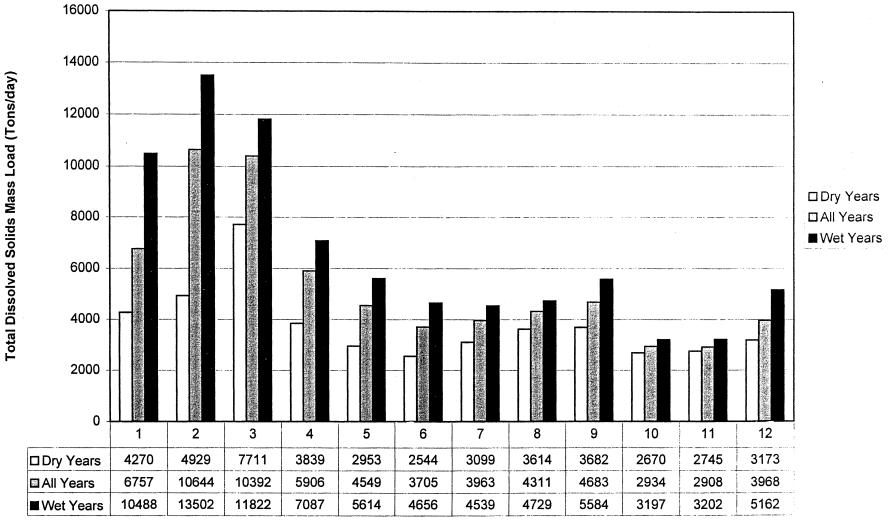
Cumulative frequencies of TDS concentrations in the Sacramento River at Greenes Landing are presented in Figure 6-12. Inspection of this figure yields the information that virtually all readings fall within the 75 to 200 mg/L range, indicating mineral quality at that location is consistently good and is not highly variable. Figure 6-13, which presents cumulative frequency of TDS loadings at Greenes, demonstrates that about 80 percent of the time, loadings are less than 10,000 tons/day, but that loadings up to about 20,000 tons/day have been observed.

Mallard Island

Figure 6-14 presents historical TDS concentrations in the Sacramento River at Mallard Island. Fluctuations are pronounced, indicating the importance of tidal action at this

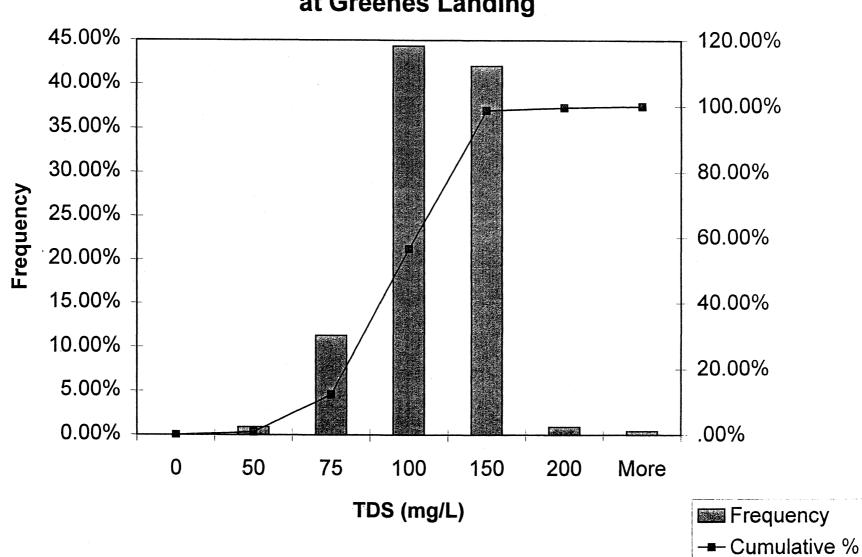
TDS in Sacramento R @ Greenes Landing

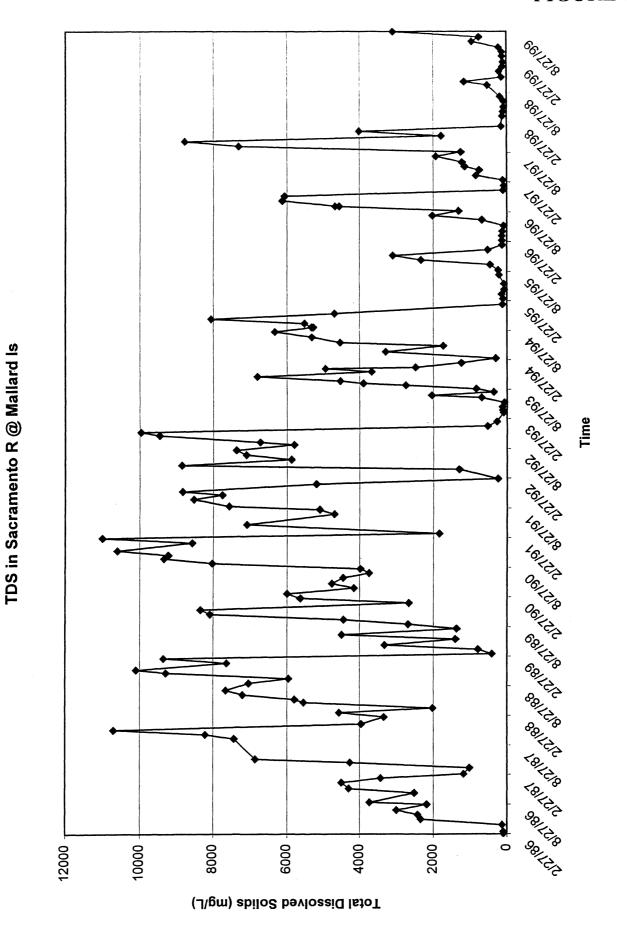




Month







location. The degree to which these salts affect drinking water supplies taken from the Delta is a function of tide and fresh water outflow.

Figure 6-15 shows monthly average TDS concentrations for different hydrologic year types. Concentrations are significantly higher in all months of dry years. Figure 6-16 shows that TDS concentrations are distributed over a wide range, but are most often in the 1000 to 2000 mg/L range.

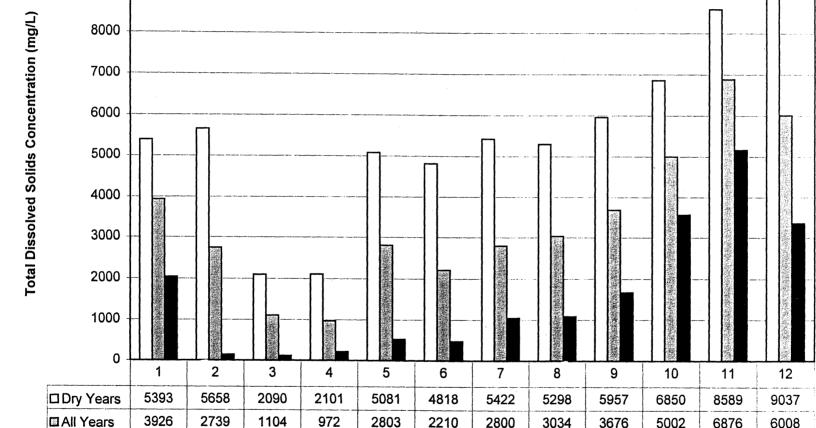
San Joaquin River

Figure 6-17 depicts TDS concentration and loading history in the San Joaquin River near Vernalis. This record was derived from samples collected by the Department of Water Resources (DWR), Figure 6-18 represents historical TDS estimates derived from continuous recording of specific conductance (EC), based on computation of TDS by application of an equation derived by performing a regression analysis of actual EC and TDS data collected by DWR. Both forms of analysis produced similar results, but the values derived from continuous recording are probably a more accurate representation. The pattern of these data demonstrates that there is generally an inverse relationship between TDS concentration and loading. This reflects the ability of higher flow volumes to dilute TDS concentrations. In both figures, a typical delay can be observed between the time loads increase and concentrations decrease. This observation is consistent with the hypothesis that increased flows have significant salt dilution benefits.

Figure 6-19 shows mean monthly TDS concentrations in the San Joaquin River near Vernalis. Dry conditions consistently result in higher TDS concentrations, reflecting reduced dilution of salts; whereas, wet conditions consistently produce the opposite effect. This effect is more pronounced in February, where the TDS difference between wet and dry conditions can amount to about 500 mg/L, whereas in the Sacramento River the difference is an order of magnitude smaller for that month. By comparison to the Sacramento River, therefore, TDS concentrations at Vernalis are much more variable and dependent on river flow.

TDS loadings in the San Joaquin River near Vernalis are shown in Figure 6-20. February, March and April are associated with the highest loadings, and the highest variability over different hydrologic conditions. Loadings are higher in all months of wet years, as compared to dry years.

Figure 6-21 and Figure 6-22 summarize the frequency of TDS concentrations and loadings, respectively, in the San Joaquin River near Vernalis. The cumulative frequency of TDS concentrations as depicted on the former Figure is bimodal, with concentrations over 300 mg/L occurring about 60 percent of the time. The most frequent concentration to be observed was in 500 mg/L to 600 mg/L range. The bimodal (two peaks) appearance of the figure may reflect the strikingly different water quality that occurs in the San Joaquin River. During high flow events mineral quality can be quite good, as compared to low flow periods when the influence of agricultural drainage can be predominant.



■Wet Years

FIGURE 6-15

□ Dry Years

□ All Years

TDS in San Joaquin River near Vernalis

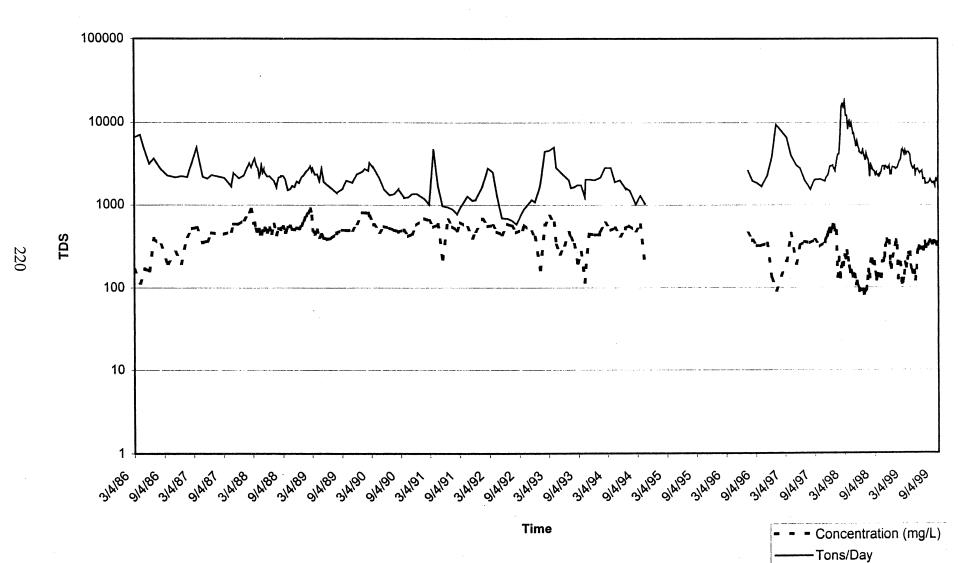


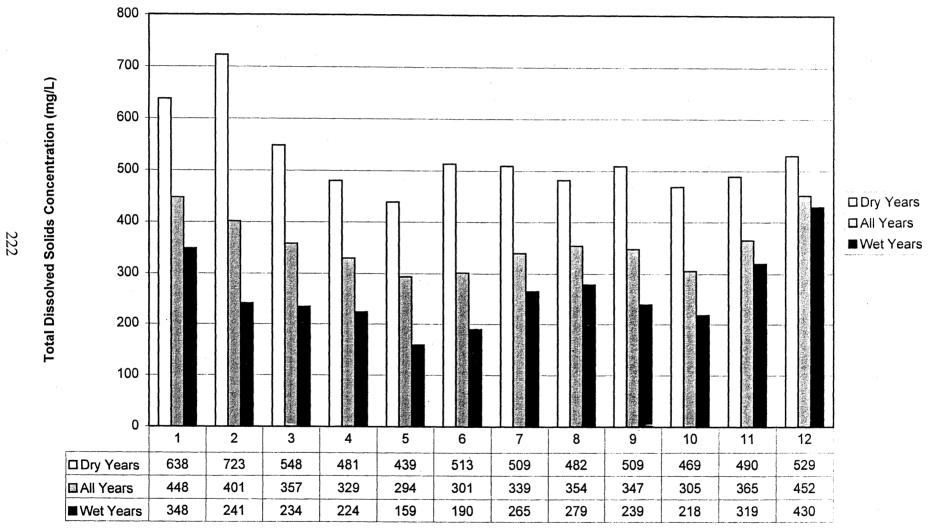
FIGURE 6-17

· Tons/Day - mg/L Time 10000 100000 1000 100 9 SQT

TDS in San Joaquin River near Vernalis (Derived from Continuous EC Measurements)

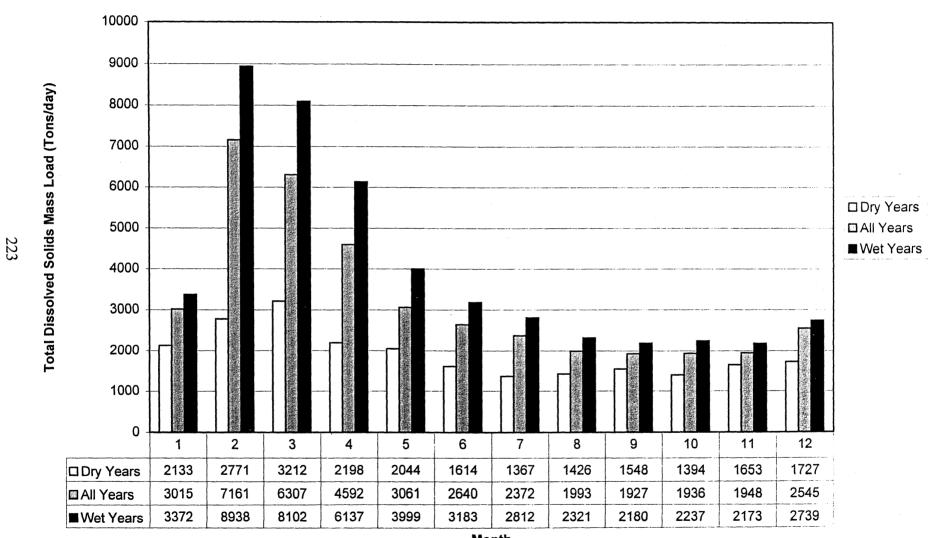
FIGURE 6-19

TDS in S.J.R. nr. Vernalis



Month

TDS in S.J.R. nr. Vernalis



Month

Figure 6-22 indicates that about 80 percent of the time, TDS loading occurs at or below 4000 tons per day, with nearly half of the observations falling in the 2000 to 4000 tons/day range.

American River

In this analysis, the quality of American River water is represented by samples taken from the intake to the Sacramento water treatment plant, located on the lower American River near Howe Avenue, upstream of its confluence with the Sacramento River.

Figure 6-23 demonstrates historical TDS concentrations measured at the location. Concentrations are quite low and constant. Variations in mass loading will, therefore, be caused primarily by flow changes. Figure 6-24 shows monthly average TDS concentrations, and indicates that dry years are associated with marginally higher TDS. Figure 6-25 shows the importance of flow with regard to mass loads of TDS, the wet months of wet years being associated with significantly higher loads. Figure 6-26 and Figure 6-27 demonstrate that most TDS concentrations are measured in a range of 50 to 100 mg/L, and that about 80 percent of mass loads fall in the range of 50 to 800 Tons/day, small in comparison to the Sacramento River.

Discharges

Total dissolved solids in discharges of treated waste water, storm water drainage, and Delta island drainage are characterized here.

Sacramento Storm Drainage

Based on 133 storm drain samples collected from six Sacramento area locations over the period August 1991 through September 1998, the average TDS in Sacramento storm drain samples was 108 mg/L, with a standard deviation of 92 mg/L.

Sacramento Regional Waste Water Treatment Plant

Based on four recent years' data, the average TDS concentration in the treated effluent of the regional treatment plant is about 390 mg/L and the average mass load is about 270 tons per day.

Stockton Storm Drainage

Based on 20 samples of storm water drainage collected from the City of Stockton, TDS concentration in this drainage averages about 72 mg/L TDS.

Stockton Waste Water Treatment Plant

Based on analysis of 158 samples collected during the period January 1995 through July 2000, the average TDS concentration in the treated effluent of the City of Stockton's waste water treatment plant is about 730 mg/L, and the average mass load is about 96 Tons/day.